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Geology, Mineral Chemistry and Thermobarometry of the Entwine Stock, Northwest Ontario: Base Metal, Platinum Group Element and Gold Mineralization

by

D. Stone

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Abstract

The Entwine Stock is a 35-km long intrusion of the late Archean sanukitoid suite in the west-central Wabigoon Subprovince of northwest Ontario. Regionally, the Entwine Stock is composed of diorite, monzodiorite, monzonite to granite and rare hornblendite. The diorite is composed of orthopyroxene, clinopyroxene, biotite, amphibole, plagioclase, magnetite and ilmenite and is variably altered to an assemblage of epidote + actinolite + chlorite + albite + quartz + calcite. Diorite at the western end of the Entwine Stock is locally mineralized with a few percent disseminated sulphides including chalcopyrite, pyrite, pyrrhotite and pentlandite and yields assays of platinum, palladium and gold typically in excess of 1 gram/tonne. Platinum and palladium occur as bismuthides and bismuth-tellurides commonly in small grains of 1 to 10 μm size. Gold is observed as small grains of electrum in pyrite.

Pyroxene thermometers and barometers suggest that the magma began to crystallize at temperatures of 900°C and pressures possibly as high as 10 kbar. Al-in-hornblende barometry indicates that the final stages of crystallization possibly representative of the depth of emplacement of the Entwine Stock took place at pressures of about 4 kbar. Alteration of the diorite probably occurred at temperatures of 380 to 475°C and pressures of 2 to 4 kbar.

Although some sulphide grains occur in fresh diorite in contact with "primary" minerals such as pyroxene, the majority of sulphide grains and all observed platinum group minerals are associated with "secondary" silicates (actinolite + chlorite + epidote). These mineral associations imply that the economic minerals were either introduced to the diorite or else remobilized within the diorite under greenschist conditions, possibly in relation to the movement of hydrothermal fluids.

Introduction

Plutonic rocks underlie vast areas of the western Superior Province but have historically been overlooked in the search for economic minerals. Among the broad spectrum of suites of plutonic rocks are intermediate to felsic intrusions of the late Archean sanukitoid suite (Shirey and Hanson, 1984; Stern et al. 1989) of which the Entwine Stock is a member. Regional mapping (Stone, Hallé and Chaloux 1998, Stone and Hallé 1999) has led to subdivision of the Entwine Stock into units including hornblendite, diorite, monzodiorite and monzonite to granite. The dioritic phases host occurrences of base metals and platinum group metals including gold that have been known since the 1970s and are currently being explored. During the regional mapping, samples were collected from mineral showings and exploration drillcore for assay, petrography and analysis of mineral chemistry. The following is a brief account of the geology of the Entwine Stock and the mineral associations including mineralogy of the platinum group element (PGE)-enriched zones. The work is intended to characterize the mineralogy of PGE showings in the Entwine Stock and to define the environment in which mineralization might be found in other sanukitoid plutons throughout the western Superior Province.

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Regional Geologic Setting of the Entwine Stock

The Entwine Stock is situated in the Archean Wabigoon Subprovince of northwest Ontario. Blackburn et al. (1991) subdivided the Wabigoon Subprovince into western, central and eastern regions. Within this framework, the Entwine Stock lies more-or-less at the interface between the western and central regions but is provisionally included with the central region because plutonic and gneissic country rocks of the Entwine Stock appear to represent a continuum with similar rocks in the central region.

The geology of the western Wabigoon region is characterized by 2.75 to 2.71 Ga greenstone belts of overall east-northeast trend that envelope large elliptical felsic batholiths. The greenstone belt at Upper Manitou Lake (Figure 1) is representative of the western Wabigoon region and is composed of ultramafic through mafic to felsic volcanic sequences and a lesser component of alluvial fan-fluvial and turbiditic sedimentary sequences. Blackburn et al. (1991) has subdivided the Upper Manitou greenstone belt into volcanic and sedimentary groups including the mafic metavolcanic Wapageisi group that comprises the crescentic southern part of the belt (Figure 1). Thin units of amphibole gneiss, possibly representative of the Wapageisi group are interleaved with tonalite gneisses at margins of the Entwine stock.

The central region of the Wabigoon Subprovince (Figure 1) has a high proportion of felsic plutonic and gneissic rocks in comparison with greenstone sequences. The central Wabigoon region is further distinguished from the western Wabigoon region by an extensive domain within which supracrustal and plutonic rocks have Mesoarchean ages. The old domain includes the 2.9 to 3.0 Ga greenstone belts at Finlayson and Lumby Lakes and the 3.0 Ga Marmion batholith (Davis and Jackson, 1988), and is intruded by younger plutonic rocks represented by the 2.69 Ga White Otter Batholith (D. Davis, personnal communications, 1993). Although the boundaries between young and old plutonic rocks are locally intrusive, the overall geologic and tectonic relations between the old and young crustal domains are poorly understood and are the focus of ongoing regional mapping in the central Wabigoon Subprovince (e.g. Stone and Hallé 1999). Tectonic models (e.g. Tomlinson et al. 1999) suggest that the southern part of the central Wabigoon region may represent a Mesoarchean crustal fragment incorporated by accretionary tectonics into

juvenile supracrustal sequences represented by the western Wabigoon region and subsequently intruded by late plutons.

The eastern Wabigoon region is centred more than 200 km east of the present area and comprises easterly elongate greenstone belts interleaved with sedimentary sequences in the Beardmore–Geraldton area giving way northward to batholithic complexes and large greenstone sequences such as the Onaman–Tashota belt. Stott, Davis and Parker (1998) subdivided the Onaman–Tashota belt into tectonostratigraphic blocks including a Mesoarchean block in the north that possibly represents a continuum with the northern central Wabigoon region and the Winnipeg River Subprovince.

Geology and Structure of the Entwine Stock

The Entwine Stock is elongate 35 km west northwesterly and attains a maximum width of 8 km at the western end. The intrusion lies within country rocks comprising mainly biotite tonalite and tonalite gneiss. A thin (up to 500 m) unit of amphibolite, probably representative of mafic metavolcanic rocks, mantles the oval western end of the Entwine Stock (Figure 2).

The Entwine Stock was originally mapped by Davies (1965) and subsequently re–examined by Stone, Hallé and Chaloux (1998) and Stone and Hallé (1999) who identified four principal lithologic components of the intrusion.

DIORITE, MONZODIORITE

Diorite, locally grading to monzodiorite occurs in an oval to irregular domain at the west–end of the Entwine Stock and as thin units at the south side of the intrusion (Figure 2). Diorite is typically massive, medium to coarse and very coarse grained and grey to white or brownish in colour. Mafic to ultramafic schlieren and inclusions are present and diorite locally shows very faint magmatic layering characterized by slight changes in mafic mineral content.

Fresh diorite is typically composed of 15 to 30% clinopyroxene, orthopyroxene, amphibole and biotite in plagioclase with accessory K feldspar, quartz, apatite, titanite, magnetite and ilmenite. Where altered, diorite is brownish and friable and is composed of actinolite + epidote/zoesite + chlorite + sericite + albite + calcite. Sulphides including chalcopyrite, pyrite, pyrrhotite and pentlandite and rare PGE–tellurides occur locally in diorite and tend to be concentrated in altered zones.

MONZODIORITE, MONZONITE

Monzodiorite to monzonite is widespread comprising most of the eastern "tail" of the Entwine Stock. Monzodiorite to monzonite is medium– to coarse–grained, pink to red and can be variably massive to foliated or lineated. A mineral assemblage comprising 15 to 25 % clinopyroxene, amphibole and biotite with sub–equal proportions of plagioclase and K feldspar and accessory quartz, apatite, titanite, magnetite and ilmenite is representative of monzodiorite to monzonite. Plagioclase is partly altered to zoesite and amphibole, pyroxene and mica grains are locally rimmed by chlorite.

QUARTZ MONZONITE, GRANITE

Quartz monzonite to granite occurs primarily in two small domains at the northwest end of the Entwine Stock (Figure 2). It is coarse to very coarse grained, massive and pink to red with distinct K feldspar megacrysts. Quartz monzonite to granite is composed of 10 to 20 % amphibole and biotite with plagioclase, K feldspar and quartz and accessory apatite, titanite, magnetite and ilmenite. Crosscutting relations suggest that quartz monzonite postdates diorite and monzonite.

HORNBLENDITE, PYROXENITE

Coarse, black hornblendite to pyroxenite occurs at scattered locations in the Entwine Stock in forms ranging from schlieren and inclusions to dikes and a oval plug of 2-km diameter. Rare dikes of hornblendite to pyroxenite also cut tonalitic country rocks south of the Entwine Stock. The oval pyroxenite plug that intrudes monzodiorite in the eastern "tail" of the Entwine Stock (Stone, Hallé and Chaloux 1998) is composed of about 60% clinopyroxene with amphibole, phlogopite, magnetite, apatite and K feldspar. Smaller ultramafic bodies tend to be dominated by amphibole.

DIKES, FRACTURES AND FAULTS

Intermediate to felsic and variable aplitic to pegmatitic dikes and irregular masses of granodiorite-granite transect other phases of the Entwine Stock although typically in minor proportions. Epidote-filled fractures and mesoscopic faults are also observed in outcrops. Two, regional north-northeast striking brittle faults cut the western end of the Entwine Stock (Figure 2) and show up to 1 km of sinistral strike separation.

A mylonite zone of up to a few hundred meters width is developed in country rocks and in monzodiorite at the northwest end of the Entwine Stock and appears to closely follow the contact of the intrusion. The fabric of the mylonite and enveloping gneisses dips eastward at shallow to intermediate angles (Figure 2). This, combined with shallow, easterly plunging mineral lineations within the Entwine Stock implies that the northwest end of the intrusion plunges east to southeasterly.

Mineral Exploration and Assay Results

Davies (1965) noted that parts of the Entwine Stock were staked in the early 1960s following release of an aeromagnetic map (ODM-GSC, 1965) that showed a distinct magnetic anomaly associated with the intrusion. The Entwine Stock was subsequently explored by Noranda, BP/Selco-Southern Era and recently by Champion Bear Resources Ltd. The initial exploration appears to have focused on base-metal potential associated with several sulphide showings in the western end of the intrusion and numerous pits and trenches that probably resulted from this work in the 1970s were observed. The latest work by Champion Bear Resources Ltd has been directed at evaluation of platinum-group elements (PGEs) and gold associated with sulphides in the "Campbell Zone" at the north side of the oval western end of the Entwine Stock (Figure 2). Results of a 1999 drilling program by Champion Bear Resources Ltd indicate an average grade in excess of 1.0 g/t combined Au, Pt and Pd, 3.8 g/t Ag and .5% Cu and Ni over a true width of 25 m in the 1100 m-long "Campbell Zone" (www.championbear.com).

During regional mapping in 1999, a series of samples were collected from surface showings and from drill core generously donated by Champion Bear Resources Ltd. The showings are associated with the dioritic phase of the Entwine Stock and are located in two principal areas extending southeast from the "Campbell Zone" and north of Entwine Lake in the area of the "Moosehorn Showing" (Figure 2). Samples were submitted to the Geoscience Laboratory in Sudbury for analysis of base metals, PGEs, gold and silver. Results, (Table 1) indicate that metals including Cu, Co, Zn and Ni comprise up to 1.2% of samples from the "Campbell Zone", "Moosehorn Showing" and other showings. Copper is the most abundant base metal followed by nickel. Cobalt and zinc have subsidiary and sub-equal concentrations.

Combined Pt, Pd and Au concentrations range up to 1.2 ppm for samples from the "Campbell Zone" (Table 1). On average, Pd exceeds Pt by a ratio of 1.6:1 and Pt exceeds Au by a ratio of 1.4:1. Samples from outside the "Campbell Zone" show sporadic low concentrations of Au; Pt and Pd are below detection limit. Ag is uniformly below detection limit (.34 ppm) for the fire assay method.

Petrography and Mineral Chemistry

Polished thin sections were made from a representative suite of the assayed samples. These were examined by microscope and subsequently by the JEOL scanning electron microscope and the CAMECA microprobe of the Geoscience Laboratory. Initial microscope examination showed a range of silicate minerals in the samples possibly reflecting variable alteration. Four samples, representing the mineralogic spectrum are described here.

99DS46 (FRESH DIORITE)

Sample 99DS46 was obtained from an exploration trench at the southeast end of the "Campbell Zone" (Figure 2). In hand specimen, it is coarse-grained, massive and brownish showing about 10% combined sulphides, oxides, and spinel (magnetite). Under the microscope (Figure 3a) sample 99DS46 is characterized by large aggregates of mafic minerals including clinopyroxene, orthopyroxene, amphiboles, biotite and opaque minerals with plagioclase.

Compositions of clinopyroxene and orthopyroxene are diopside/augite and clinoenstatite, respectively (Table 2). Plagioclase is the most abundant mineral, occurring as large laths (An_{39}) and is locally altered to albite (Table 3). Actinolite (Mg/Mg+Fe=0.7) is the dominant amphibole forming aggregates and rims on clinopyroxene. Anthophyllite occurs as rims on orthopyroxene. Biotite grains are distinctly dark brown to reddish in thin section and can be slightly altered to chlorite. Biotite in sample 99DS46 has an average Fe/Fe+Mg ratio of .54 and $Al^{iv} = 2.56$ (Table 4) and is intermediate between siderophyllite and annite end-member compositions. Ilmenite and magnetite occur together in irregular aggregates (Figure 3b, Table 6) typically in contact with clinopyroxene, plagioclase and biotite.

Secondary silicates including chlorite, epidote/zoesite, calcite, quartz and sericite are found in minor proportions in sample 99DS46. Chlorite occurs mainly as an alteration product of amphibole and biotite and is of mainly ripidolite and brunsvigite composition (Table 7). Epidote group minerals occur as "cloudy" alteration products of plagioclase and as a rim on certain sulphide grains. Epidote group minerals are mainly of epidote composition (Table 8) but show a range of Fe^{3+}/Al^{vi} ratios representing a compositional spectrum between clinozoisite and epidote. Calcite, quartz and sericite occur in small proportions typically as small grains associated with sulphides (Figure 3c).

Sulphides comprise about 5% of sample 99DS46 and consist of chalcopyrite, pyrite and pyrrhotite in decreasing order of abundance. Representative compositions of sulphide grains are given in Tables 9 to 12. Some sulphide grains are in contact with "primary" silicates such as pyroxenes, plagioclase and biotite as well as oxides. Other sulphide grains are associated with secondary silicates. For example, epidote and calcite commonly form rims on sulphides such as in the upper left corner of Figure 3a and in Figure 3c.

PGEs occur with bismuth and tellurium in tiny, bright grains of 1 to 10 μm size associated with secondary silicates and chalcopyrite. The PGE grains in Figure 3c appear to be representative of merenskyite and an unknown mineral comprising sub-equal atomic proportions of Pd and combined Bi and Te (Table 13).

99DS49e (WEAKLY ALTERED DIORITE)

Sample 99DS49e is taken from 61.0 m depth in borehole ER1 at the "Campbell Zone" (Figure 2). Under the microscope, a thin section of sample 99DS49e (Figure 4a) shows essentially the same mineralogy as sample 99DS46 but with a higher proportion of secondary minerals.

Two pyroxenes comprising Ca-rich augite and clinoenstatite (Table 2) are present and are variably altered to amphibole. The orthopyroxene tends to be most altered and occurs as rounded relicts within

aggregates of amphibole grains. Three varieties of amphibole are recognized. Actinolite (Table 5) occurs widely and a few grains of magnesio hornblende are identified. The latter, aluminous amphibole is common in monzodiorite and monzonite of the Entwine Stock. A third variety of amphibole is sub-calcic and probably represents anthophyllite.

Biotite occurs in a range of forms including large brown grains, intergrowths with actinolite and as rims on sulphide and oxide grains (Figure 4c, d). Biotite is locally altered to chlorite. Primary plagioclase occurs as large laths (An_{43}; Table 3), which are partly converted to zoisite, sericite and albite.

In addition to amphibole, secondary silicates include chlorite, epidote/zoisite, sericite, quartz and albite. Chlorite appears to have developed by the breakdown of amphibole and biotite whereas epidote group minerals and sericite occur mainly with altered feldspars. Fine epidote, chlorite, albite and quartz are also associated with sulphide grains (Figure 4b, 4e).

Sulphides including chalcopyrite, pyrite, pyrrhotite, pentlandite and rare galena as well as oxides (ilmenite and magnetite) comprise about 5 % of the sample (Figures 4b, 4c and 4d). Oxides are typically associated with "primary" minerals such as pyroxene and plagioclase and many oxide aggregates are surrounded by biotite (Figure 4d). Sulphide grains show a bimodal occurrence. Some sulphide grains such as in Figure 4d occur with oxides and "primary" silicates however, the majority of sulphide grains occur within altered zones in association with "secondary" silicates such as in Figure 4b. A small grain of palladium-bismuthide possibly representative of sobolevskite or froodite is identified in the energy spectrum of the scanning electron microscope (Figure 4f).

99DS50F (MODERATELY ALTERED DIORITE)

Sample 99DS50f is obtained from drillcore at the 34.2 m depth in borehole ER10 from the "Campbell Zone". A thin section of 99DS50f (Figure 5a) shows mainly secondary silicates and up to 10% sulphides and oxides. Pyroxenes are absent from the section and relict plagioclase grains (An_{46}) are extensively altered to albite (Table 3), zoisite and sericite. Partly chloritized biotite (Table 4) and actinolitic amphibole (Table 5) are the most abundant mafic silicates. Magnetite and ilmenite are present in minor proportions and commonly form skeletal intergrowths with biotite.

Epidote group minerals (Table 8) occur within intensely altered zones in feldspars and as euhedral clear grains surrounding sulphide aggregates. Chlorite (Table 7) is commonly associated with biotite and occurs together with zoisite, albite, K feldspar and calcite in close association with sulphides (Figure 5b, 5c). Large euhedral apatite grains (Figure 5a) appear to have developed in altered zones.

Sulphide minerals include chalcopyrite, pyrite, pyrrhotite, pentlandite and rare galena and typically occur within zones of secondary silicates. Small grains of electrum (Figure 5d, Table 13) are identified in pyrite grains (Figure 5b). Electrum was also noted within pyrite and chalcopyrite grains in sample 99DS42b and appears to be the principal mode of occurrence of gold and silver. Small grains of Pt-Bi telluride (Figure 5e, Table 13), probably representative of moncheite are identified in secondary silicate minerals at the margins of a sulphide grain (Figure 5c).

99DS50b (STRONGLY ALTERED DIORITE)

Sample 99DS50b is obtained from drillcore at the 24.0 m depth in borehole ER10 of the "Campbell Zone". In thin section (Figure 6a), 99DS50b shows mainly secondary minerals with a few relict grains of plagioclase and magnetite. Plagioclase appears to have been converted to fine aggregates of sericite, zoisite and albite (Table 3). Amphiboles with compositions transitional between magnesio hornblende (Table 5) and actinolite are common and are locally rimmed by epidote group minerals. Biotite is rare and appears to be converted to chlorite and calcite. Ilmenite and magnetite are less common than in fresh diorite and are replaced by aggregates of chlorite, titanite and calcite.

Epidote group minerals, chlorite and calcite are much more common here than in less altered diorite. Large, euhedral epidote grains (Table 8) occur with chlorite, at rims of amphibole and as irregular masses commonly associated with disseminated sulphides. Green to brown felted aggregates of chlorite are mainly of brunsvigite composition (Table 7) and appear to have replaced biotite, locally amphibole and oxides. Calcite occurs widely as small grains, typically associated with chlorite.

A wide variety of sulphide minerals including chalcopyrite, pyrite, pyrrhotite, pentlandite and millerite are identified (Tables 9-12; Figure 6b). Trace quantities of other minerals possibly including bornite, violarite and an oxide of Pb are discerned in the energy spectra of the scanning electron microscope. Small grains of Pt-Bi telluride and Pd-Bi telluride are noted in a pyrite grain (Figure 6c). These are representative of moncheite and an unknown and non-stoichiometric mineral such as $(Pd,Bi)_2Te$ (Table 13).

Mineral Chemistry of Oxides, Sulphides, Electrum and PGE Minerals

OXIDES

Oxides, including ilmenite and magnetite, comprise up to a few percent of diorite and are more abundant in fresh rock than in altered rock. Oxides occur in contact with "primary" minerals such as pyroxene and plagioclase in fresh diorite and are rimmed by and intergrown with biotite in progressively more altered diorite.

The compositions of ilmenite grains are fairly uniform from sample to sample and are characterized by molecular proportions of 95 to 97% of the ilmenite molecule with the remainder mainly hematite (Table 6). Magnetite has a fairly pure iron end-member composition with up to 1% impurities comprising mainly Cr and V (Table 6). The ulvospinel component (Fe_2TiO_4) of the magnetite is very small.

SULPHIDES

Sulphide minerals typically comprise a few percent and locally up to 10% of diorite and include chalcopyrite, pyrite, pyrrhotite, pentlandite and millerite in approximate decreasing order of abundance. Small grains of galena occur both in other sulphides and with secondary silicates. Trace quantities of benjaminite, violarite and bornite are observed in the energy spectra of the scanning electron microscope.

The majority of sulphide grains occur as disseminations ranging in size from a few microns to millimeters and are closely associated with secondary silicates including epidote, chlorite, calcite and albite. In relatively fresh diorite, sulphide grains are observed in contact with primary minerals including pyroxenes, plagioclase, biotite and oxides.

Chalcopyrite compositions (Table 9) are representative of fairly pure $CuFeS_2$ with only trace amounts of Ni and Zn. Pyrite can contain up to a few percent of Co and Ni (Table 10) and together with pentlandite, appears to be the principal host for Co. Pyrrhotite and pentlandite typically occur together with pentlandite forming lamellae and blebs within pyrrhotite. The analyzed grains of pyrrhotite (Table 11) contain an average of .8% Ni. In addition to Ni and Fe, pentlandite contains 3.7% Co. A few, small, brownish grains of millerite that are partly intergrown with silicates were analyzed (Table 12).

ELECTRUM

Electrum was observed in two sections and appears to be the principal host for gold and silver. In both instances, the electrum occurs as irregular blebs of about 10 μm size within pyrite. Analyses of electrum in 99DS50f have 30% silver (Table 13).

PGE MINERALS

Platinum and palladium are observed as bismuthides and bismuth-tellurides in small grains of 1 to 10 μm size. These PGE minerals occur both in sulphides and in silicates but are always associated with clusters of secondary minerals. The PGE minerals are qualitatively identified in the energy spectrum of the scanning electron microscope and in some instances can be analyzed by microprobe although the small grain size commonly causes the analysis to be contaminated by material surrounding the PGE grain.

The analyzed PGE minerals (Table 13) are non-stoichiometric either due to contamination of the analyses or due to solid solution between phases. Minerals containing Pt can be approximated by the end-member composition of moncheite. Pd occurs with Bi as froodite or sobolevskite and with Bi and Te as merenskyite and several unknown minerals.

Thermobarometry

A variety of thermometers and barometers were applied to various mineral assemblages to constrain the temperature and pressure conditions under which the magma of the Entwine Stock evolved and crystallized and was subsequently altered.

TWO PYROXENE THERMOMETRY

Two pyroxene geothermometry is based on the distribution of Ca and Mg between coexisting clinopyroxene and orthopyroxene. The exchange reaction

$$2 \text{ hedenbergite} + \text{enstatite} = 2 \text{ diopside} + \text{ferrosalite} \qquad (1)$$

is evaluated using the program TWQ of Berman (1991) and the thermodynamic data of Berman (1988). Two samples (Table 14) give fairly consistent temperatures in the range of 850 to 940°C over a broad range of pressures from 5 to 10 kbar. These are thought to represent temperatures at an early stage of magma evolution as pryoxenes crystallized and equilibrated.

MAGNETITE-ILMENITE THERMOMETRY

The solution model for coexisting iron-titanium oxides of Spencer and Lindsley (1981) was evaluated for magnetite-ilmenite pairs (Table 6) in the samples of the Entwine Stock. It was found that magnetite was very nearly of the pure Fe_3O_4 endmember composition and a correspondingly low content of the ulvospinel molecule. These compositions are representative of metamorphic conditions on the order of 500°C. Evidently, magnetite and ilmenite either developed or were metamorphically re-equilibrated at temperatures of about 500°C. Petrographic evidence including the association of oxides with pyroxene favour the second option in which oxides developed at high temperatures and exsolved or oxidized on cooling possibly in relation to the greenschist alteration that is common in diorite.

SCAn BAROMETER

The equilibrium among anorthite, quartz and the Ca-tschermak component in clinopyroxene

$$CaAl_2SiO_6^{Cpx} + SiO_2^{Qtz} = CaAl_2Si_2O_8^{Pl} \qquad (2)$$

has been calibrated as a barometer by McCarthy and Patino Douce (1998) for clinopyroxene-bearing granulites. This barometer was tested on coexisting clinopyroxene and plagioclase in the Entwine Stock at

a temperature of 900°C and yielded pressures ranging from 5 to 10 kbar (Table 14). Although the barometer provides evidence for high pressures, possibly representative of an early stage of magma crystallization, the results are difficult to interpret in view of limited testing and highly variable pressure determinations. The barometer was calibrated for granulites and requires the presence of quartz, which is rare in the igneous rocks of the Entwine Stock. Detailed petrographic study is warranted to confirm igneous quartz in the tested assemblages. Further, the effect of coexisting orthopyroxene and clinopyoxene is unknown and the barometer needs to be tested on Opx-present and Opx-absent assemblages.

AMPHIBOLE-PLAGIOCLASE THERMOMETER AND AL-IN-HORNBLENDE BAROMETER

The amphibole-plagioclase thermometer of Holland and Blundy (1994) has been incorporated into the temperature-corrected barometer of Anderson and Smith (1995) and applied to hornblende-bearing rocks of the Entwine Stock. Details of these equilibria are provided by Stone (in press). Results (Table 14) indicate temperatures in the range of 687 to 757°C and pressures of 3.0 to 4.1 kbar. Given the widespread occurrence of amphibole and petrographic evidence for amphibole developed as rims on pyroxene, the results are thought to represent late magmatic conditions under which the Entwine Stock was emplaced and cooled. Al-in-hornblende pressures in the Entwine Stock are lower by about 1 kbar on average than pressures determined by the same method on country rocks (unpublished data). Relatively low Al-in-hornblende pressures are a characteristic of sanukitoid plutons (Stone, in press) and probably indicate that these intrusions were emplaced at higher levels than older hornblende bearing rocks in the region.

STABILITY FIELDS OF GREENSCHIST MINERALS AND ASSEMBLAGES

Pressure-temperature conditions of alteration in the Entwine Stock are constrained with reference to the stability fields for various index minerals and assemblages (Figure 7). The widespread occurrence of an assemblage of epidote + actinolite + chlorite (+albite + calcite) is represented by the field labelled CZ + ACT + CHL in Figure 7 and indicates temperatures less than 475°C. Zeolite minerals and prehnite were not observed in samples of the Entwine Stock and imply a lower temperature limit of 380°. Assuming that alteration occurred at pressures less than or equal to those at which the Entwine Stock was emplaced (about 4 kbar by Al-in-hornblende) then it can be estimated that alteration took place at temperatures of 380 to 475°C and pressures less than 4 kbar and likely in the range of 2 to 4 kbar.

Kamineni et al. (1988) noted that prehnite and minerals of the zeolite facies tend to occur mainly in fractures within altered plutonic rocks. Fractures were not systematically studied in the Entwine Stock and may warrant further investigation to establish lower limits of ambient conditions of alteration.

Conclusions

Several generalized conclusions can be drawn from the study:

1) The Entwine Stock is a member of the sanukitoid suite of intermediate to felsic intrusions in the western Superior Province of northwest Ontario. It is composed of diorite, monzodiorite, monzonite and local hornblendite/pyroxenite.

2) Unaltered diorite of the Entwine Stock is composed of two pyroxenes, plagioclase, amphibole and biotite as well as magnetite and ilmenite. Diorite is locally mineralized with a few percent sulphides (chalcopyrite, pyrite, pyrrhotite and pentlandite) and PGE tellurides and bismuthides and electrum.

3) The diorite is variably altered to an assemblage of "secondary" minerals representative of greenschist metamorphic grade. The minerals include actinolite, chlorite, epidote, sericite, albite and calcite.

4) Sulphides are locally associated with "primary" minerals including pyroxenes, plagioclase and oxides in "fresh" diorite however the majority of sulphides, PGE minerals and electrum occur with "secondary" silicates.

5) Thermobarometry suggests that crystallization of the magma initiated at temperatures of 850 to 950°C and pressures of 9 to 10 kbar. The Entwine Stock was emplaced at a depth corresponding to pressures of about 4 kbar. Alteration occurred at temperatures of 380 to 475° and pressures probably in the range of 2 to 4 kbar.

The strong association of sulphides and PGE minerals with altered diorite suggests that these minerals were remobilized under greenschist conditions, possibly in relation to the circulation of hydrothermal fluids. The scale of remobilization is unclear however and further work is required to determine if the economic minerals were introduced to the host rock or redistributed locally within the diorite during alteration.

Using the "Campbell Zone" as a model for PGE mineralization in other sanukitoid intrusions, the first-order exploration criterion is the greenschist alteration represented by a mineral assemblage of actinolite + chlorite + epidote + albite + calcite with which a few percent sulphides are associated. The altered diorite can be recognized in the field by a friable, brownish character. Relatively fresh diorite from the "Campbell Zone" is distinguished by the presence of orthopyroxene and clinopyroxene as well as magnetite and ilmenite whereas non-mineralized sanukitoid plutons have only clinopyroxene and magnetite predominates over ilmenite. This somewhat more complex mineralogy may also provide an exploration link to PGE enriched zones in other plutons.

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Table 1: Assay results from the Entwine Intrusion (see sample locations in Figure 2)

Sample No	Area	UTM east	UTM north	Rock Type	Assay Results							
					Au ppb	Ag ppm	Cu ppm	Co ppm	Zn ppm	Ni ppm	Pt ppb	Pd ppb
99DS32	Entwine	525129	5444470	14a	<5	<.34	161	56	83	61	<8	<8
99DS36	N. Entwine	526294	5450013	14a	<5	<.34	21	26	103	51	<8	<8
99DS38A	N. Entwine	527246	5449008	14a	42	<.34	175	74	100	195	<8	<8
99DS38B	N. Entwine	527246	5449008	14a	<5	<.34	474	87	244	167	<8	<8
99DS38C	N. Entwine	527246	5449008	14a	<5	<.34	251	140	264	208	<8	<8
99DS39	N. Entwine	527435	5448578	14a	5	<.34	209	77	95	191	<8	<8
99DS42A	N. Entwine	524859	5444767	14a	14	<.34	1044	80	82	212	<8	<8
99DS42B	N. Entwine	524859	5444767	14a	29	<.34	1710	78	83	346	<8	<8
99DS42C	N. Entwine	524859	5444767	14a	17	<.34	1129	62	79	238	<8	<8
99DS46	N. Entwine	525600	5450350	14a	130	<.34	3508	58	87	449	169	285
99DS49C	ER1 42.9m	525250	5450400	14a	336	<.34	10625	91	93	1632	393	698
99DS49D	ER1 51.3m	525250	5450400	14a	317	<.34	9190	84	98	1034	408	691
99DS49E	ER1 61.0m	525250	5450400	14a	175	<.34	4334	49	76	481	201	349
99DS49F	ER1 77.0m	525250	5450400	10b	55	<.34	1709	89	163	397	99	186
99DS50B	ER10 24.0m	524950	5450600	14a	231	<.34	6281	70	82	760	355	590
99DS50C	ER10 25.5m	524950	5450600	14a	282	<.34	7643	84	84	1007	338	600
99DS50D	ER10 26.5m	524950	5450600	14a	268	<.34	8041	80	82	977	339	638
99DS50E	ER10 31.0m	524950	5450600	14a	271	<.34	7508	68	90	791	347	621
99DS50F	ER10 34.2m	524950	5450600	14a	307	<.34	9186	78	85	953	349	593
99DS50G	ER10 37.1m	524950	5450600	14a	26	<.34	431	19	41	98	32	53
99DS50H	ER10 40.0m	524950	5450600	14a	274	<.34	7581	83	81	940	407	676
99DS50I	ER10 42.4m	524950	5450600	14a	245	<.34	6436	64	77	634	308	512
99DS51B	ER11 13.6m	524500	5450850	14a	226	<.34	8842	86	100	1137	514	861
99DS51C	ER11 16.1m	524500	5450850	14a	297	<.34	5199	48	80	511	391	600
99DS51F	ER11 59.5m	524500	5450850	14a	16	<.34	302	35	90	108	<8	12

Ag is determined by fire assay; detection limit is .34 ppm
Au, Pt and Pd are determined by ICP-MS; detection limits are: Au - 5 ppb, Pt - 8 ppb, Pd - 8 ppb.
Cu, Co, Zn and Ni are determined by ICP-AES; detection limits are: Cu - 5 ppm, Co - 5 ppm, Zn - 2 ppm, Ni - 5 ppm.
For samples 99DS46, 49 50 and 51, the average ratios of Au:Pt:Pd are 1:1.4:2.3; Pt:Pd = 1:1.6

Table 2: Pyroxene analyses, Entwine Intrusion

Label	99DS118	99DS46	99DS46	99DS49c	99DS49d	99DS49d	99DS49e	99DS49e
No ansys	3 cpx	4 opx	5 cpx	3 cpx	1 opx	1cpx	2cpx	2 opx
Rock	14c?	14a	14a	14a	14a	14a	14a	14a
Area	N. of Entwine	N. Entwine	N. Entwine	ER1 42.9m	ER1 51.3m	ER1 51.3m	ER1 61.0m	ER1 61.0m
Easting	526080	525600	525600	525250	525250	525250	525250	525250
Northing	5446460	5450350	5450350	5450400	5450400	5450400	5450400	5450400
SiO2	52.89	52.17	51.77	50.80	52.10	51.51	51.14	51.47
TiO2	0.29	0.19	0.32	0.49	0.15	0.25	0.43	0.08
Al2O3	1.21	1.59	2.00	2.81	1.97	2.26	2.83	1.55
Cr2O3	0.03	0.01	0.02	0.05	0.01	0.04	0.03	0.02
MgO	14.38	21.90	13.90	12.85	21.69	12.98	12.96	19.64
CaO	20.38	1.00	21.93	21.87	2.02	21.79	21.35	0.54
MnO	0.41	0.54	0.31	0.23	0.47	0.26	0.26	0.64
FeO	9.02	22.38	9.69	9.64	21.35	10.17	10.34	25.11
Na2O	0.87	0.01	0.42	0.53	0.05	0.41	0.50	0.00
K2O	0.00	0.01	0.00	0.06	0.00	0.00	0.00	0.00
Total	99.48	99.79	100.35	99.33	99.81	99.66	99.85	99.04
Cations on the basis of 6 O								
TSi	1.97	1.948	1.921	1.909	1.941	1.933	1.914	1.965
TAl	0.03	0.052	0.079	0.091	0.059	0.067	0.086	0.035
M1Al	0.023	0.018	0.009	0.033	0.027	0.033	0.039	0.035
M1Ti	0.008	0.005	0.009	0.014	0.004	0.007	0.012	0.002
M1Fe^{2+}	0.17	0	0.213	0.232	0	0.233	0.225	0
M1Cr	0.001	0	0.001	0.001	0	0.001	0.001	0.001
M1Mg	0.798	0.976	0.769	0.72	0.968	0.726	0.723	0.962
M2Mg	0	0.243	0	0	0.236	0	0	0.155
M2Fe^{2+}	0.111	0.699	0.088	0.071	0.665	0.086	0.099	0.802
M2Mn	0.013	0.017	0.01	0.007	0.015	0.008	0.008	0.021
M2Ca	0.813	0.04	0.872	0.88	0.081	0.876	0.856	0.022
M2Na	0.063	0.001	0.03	0.039	0.004	0.03	0.036	0
M2K	0	0	0	0.003	0	0	0	0
Sum_cat	4	4	4	3.997	4	4	4	4
X Ca	42.678	2.026	44.683	46.085	4.103	45.402	44.798	1.126
X Mg	41.899	61.724	39.407	37.676	61.296	37.63	37.836	56.964
X Fe^{2+}+Mn	15.422	36.25	15.91	16.239	34.602	16.968	17.366	41.911
Name	Augite	Clinoenstatite	Diopside	Diopside	Clinoenstatite	Diopside	Augite	Clinoenstatite

Table 3: Feldspar analyses, Entwine Intrusion

Sample	99DS46	99DS46	99DS50b	99DS49e	99DS49e	99DS50f	99DS50f	99DS47
Mineral	I alb	pl	alb	pl	alb	pl	alb	plag
No Ansys	1	3	5	3	1	3	1	av of 4
Rock	14a	14a	14a	14a	14a	14a	14a	14c
Area	N. Entwine	N. Entwine	ER10 24.0m	ER1 61.0m	ER1 61.0m	ER10 34.2m	ER10 34.2m	N. Entwine
Easting	525600	525600	524950	525250	525250	524950	524950	523400
Northing	5450350	5450350	5450600	5450400	5450400	5450600	5450600	5448200
SiO2	68.46	58.16	67.36	57.09	64.82	55.62	67.28	61.72
TiO2	0.01	0.03	0.02	0.07	0.02	0.05	0.01	0.02
Al2O3	19.32	25.61	19.30	26.26	21.47	27.08	19.91	23.35
CaO	0.22	8.00	0.62	8.83	1.82	9.19	0.89	5.06
Fe2O3	0.34	0.26	0.62	0.21	0.21	0.24	0.78	0.08
Na2O	11.62	7.01	11.27	6.44	9.88	5.86	11.21	8.67
K2O	0.03	0.07	0.07	0.10	0.84	0.46	0.05	0.16
SrO	0.07	0.28	0.09	0.29	0.13	0.26	0.11	0.16
BaO	0.02	0.04	0.02	0.02	0.00	0.04	0.03	0.03
Total	100.09	99.46	99.37	99.30	99.20	98.79	100.26	99.26
Cations on the basis of 32 O								
Si	11.968	10.483	11.891	10.328	11.523	10.145	11.793	11.041
Ti	0.002	0.005	0.003	0.010	0.002	0.006	0.001	0.002
Al	3.981	5.441	4.016	5.599	4.499	5.821	4.113	4.924
Ca	0.041	1.546	0.118	1.712	0.347	1.797	0.167	0.971
Fe3+	0.045	0.035	0.082	0.029	0.028	0.033	0.103	0.010
Na	3.937	2.449	3.856	2.258	3.406	2.071	3.810	3.008
K	0.007	0.016	0.016	0.023	0.190	0.108	0.012	0.037
Sr	0.007	0.029	0.009	0.030	0.013	0.027	0.011	0.017
Ba	0.001	0.003	0.001	0.001	0.000	0.003	0.002	0.002
Charge	64	64	64	64	64	64	64	64
Ab	98.61	60.59	96.39	56.11	86.09	51.71	95.22	74.54
An	1.18	38.96	3.17	43.29	9.12	45.53	4.45	24.48
Or	0.20	0.46	0.44	0.60	4.79	2.76	0.34	0.98
Total	100	100	100	100	100	100	100	100

Table 4: Mica analyses, Entwine Intrusion

Sample	99DS42b	99DS46	99DS49c	99DS49d	99DS49e	99DS50f	99DS46
Spot	1 bio-chlor	3 bio	2 bio-phlog	1 bio-phlog	2 bio	2 bio-chl	3 sericite
Rock	14a	14a	14a	14a	14a	14a	14a
Area	N. Entwine	N. Entwine	ER1 42.9m	ER1 51.3m	ER1 61.0m	ER10 34.2m	N. Entwine
Easting	524859	525600	525250	525250	525250	524950	525600
Northing	5444767	5450350	5450400	5450400	5450400	5450600	5450350
SiO2	34.56	35.08	36.63	37.08	37.00	31.74	44.32
TiO2	1.74	3.14	4.26	4.82	1.79	1.66	0.48
Al2O3	15.08	17.40	14.50	14.48	16.96	15.77	34.60
Cr2O3	0.00	0.01	0.05	0.02	0.02	0.04	0.01
FeO*	18.57	19.25	17.74	16.63	18.82	28.08	3.24
MnO	0.14	0.05	0.08	0.05	0.08	0.09	0.01
MgO	13.14	9.37	12.24	12.84	12.16	8.86	0.99
CaO	0.22	0.08	0.00	0.02	0.05	0.06	0.02
Na2O	0.12	0.12	0.06	0.07	0.08	0.02	0.31
K2O	7.86	9.25	9.61	9.57	8.58	5.93	10.84
F	0.16	0.13	0.37	0.35	0.12	0.01	0.01
Cl	0.05	0.04	0.08	0.05	0.05	0.03	0.02
O_F_Cl	0.08	0.06	0.17	0.16	0.06	0.01	0.01
H2O	3.7	3.8	3.75	3.81	3.92	3.66	4.41
total	95.25	97.64	99.19	99.64	99.56	95.93	99.25
Cations on the basis of 24(O,OH,F,Cl) with OH+F+Cl=4; all Fe assumed to be FeO							
Si	5.470	5.440	5.569	5.575	5.566	5.190	6.020
AlIV	2.530	2.560	2.431	2.425	2.434	2.810	1.980
sum tetra	8	8	8	8	8	8	8
AlVI	0.281	0.617	0.165	0.139	0.571	0.227	3.553
Ti	0.207	0.366	0.487	0.545	0.203	0.204	0.049
Fe2	2.458	2.496	2.255	2.091	2.368	3.84	0.368
Cr	0	0.001	0.005	0.002	0.002	0.005	0.001
Mn	0.019	0.007	0.011	0.006	0.01	0.012	0.002
Mg	3.1	2.166	2.774	2.878	2.727	2.16	0.201
sum octo	6.065	5.653	5.697	5.661	5.881	6.448	4.174
Ca	0.037	0.013	0.001	0.003	0.008	0.011	0.003
Na	0.037	0.036	0.019	0.02	0.023	0.006	0.082
K	1.587	1.83	1.863	1.836	1.647	1.237	1.878
sum	1.661	1.879	1.883	1.859	1.678	1.254	1.963
Cations	15.726	15.532	15.58	15.52	15.559	15.702	14.137
CF	0.16	0.127	0.358	0.333	0.114	0.01	0.004
CCl	0.027	0.021	0.04	0.025	0.026	0.017	0.007
OH	3.907	3.926	3.801	3.821	3.93	3.987	3.994
O	24	24	24	24	24	24	24
Fe/(Fe+Mg)	0.44	0.54	0.45	0.42	0.46	0.64	0.65
Mg/(Mg+Fe)	0.56	0.46	0.55	0.58	0.54	0.36	0.35
Name	Siderophyllite	Siderophyllite	Annite	Annite	Annite	Siderophyllite	Sericite

Table 5: Amphibole analyses, Entwine Intrusion

Sample	99DS28	99DS40	99DS42b	99DS43	99DS43	99DS49d	99DS49e	99DS49e	99DS50f	99DS50h	99DS47
No. Anays	3	4	4	3 hb	2 actin	1	1 amph	3 amph	3 amph	2 amph	av of 4
Rock	14a	14b	14a	14a	14a	14a	14a	14a	14a	14a	14c
Area	Entwine	N. Entwine	N. Entwine	N. Entwine	N. Entwine	ER1 51.3m	ER1 61.0m	ER1 61.0m	ER10 34.2m	ER10 24.0m	N. Entwine
Easting	522261	528046	524859	522389	522389	525250	525250	525250	524950	524950	523400
Northing	5443167	5445553	5444767	5446702	5446702	5450400	5450400	5450400	5450600	5450600	5448200
X_{Mg}^{plag}	*0.57*	*0.56*	*0.36*	*0.42*	*0.41*	*0.27*	*0.56*	*0.86*	*0.95*	*0.94*	*0.75*
SiO_2	46.63	47.87	53.67	44.44	53.49	48.75	44.22	53.47	53.50	48.80	45.18
TiO_2	1.11	0.55	0.08	1.36	0.11	0.32	1.66	0.28	0.13	0.84	1.29
Al_2O_3	7.40	6.67	2.96	9.58	2.20	7.21	10.53	3.04	2.71	6.61	8.58
Cr_2O_3	0.07	0.03	0.01	0.01	0.00	0.00	0.17	0.02	0.01	0.01	0.02
FeO*	14.79	15.18	11.50	17.24	13.44	12.91	14.52	12.67	12.11	14.80	16.85
MnO	0.28	0.35	0.31	0.38	0.41	0.19	0.19	0.19	0.27	0.26	0.37
MgO	12.83	12.90	16.45	10.54	14.90	13.99	11.98	15.34	15.90	12.81	11.14
NiO	0.00	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0.00	0.00
CaO	11.79	11.89	11.88	11.28	12.42	12.30	12.07	12.31	12.77	12.42	11.25
Na2O	1.35	1.13	0.34	1.22	0.25	0.64	0.96	0.14	0.26	0.66	1.66
K2O	0.76	0.68	0.04	1.16	0.10	0.69	1.13	0.04	0.04	0.17	1.05
F	0.11	0.13	0.08	0.07	0.14	0.41	0.00	0.06	0.08	0.04	0.31
Cl	0.01	0.06	0.00	0.09	0.00	0.02	0.04	0.01	0.01	0.02	0.07
Total	97.12	97.43	97.32	97.37	97.46	97.44	97.46	97.57	97.78	97.43	97.78
O_F	0.04	0.05	0.03	0.03	0.06	0.17	0.00	0.03	0.03	0.02	0.13
O_Cl	0.00	0.01	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.02
O_F_Cl	0.05	0.07	0.03	0.05	0.06	0.18	0.01	0.03	0.03	0.02	0.15
Fe2O3 calc	1.86	2.21	1.10	2.59	0.87	2.08	2.72	0.37	1.36	1.94	2.11
FeO calc	13.12	13.19	10.50	14.90	12.66	11.04	12.07	12.34	10.89	13.05	14.95
H2O calc	1.97	1.95	2.05	1.94	2.00	1.85	2.01	2.05	2.05	2.02	1.84
Total	99.23	99.54	99.45	99.53	99.49	99.32	99.74	99.63	99.93	99.62	99.68
Formula average of min and max Fe3+ (Leake et al. 1997)											
Si	6.922	7.071	7.686	6.667	7.749	7.116	6.539	7.693	7.665	7.147	6.763
Al(iv)	1.078	0.929	0.314	1.333	0.251	0.884	1.461	0.307	0.335	0.853	1.237
Sum T	8	8	8	8	8	8	8	8	8	8	8
Al(vi)	0.217	0.232	0.185	0.361	0.124	0.356	0.375	0.208	0.122	0.289	0.277
Ti	0.123	0.062	0.009	0.154	0.012	0.036	0.185	0.031	0.014	0.092	0.146
Fe3+	0.207	0.246	0.119	0.293	0.095	0.228	0.303	0.040	0.147	0.214	0.238
Cr	0.009	0.003	0.001	0.001	0.000	0.000	0.020	0.002	0.002	0.001	0.003
Mg	2.838	2.840	3.512	2.357	3.217	3.045	2.641	3.289	3.397	2.797	2.486
Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe2+	1.606	1.617	1.174	1.835	1.533	1.335	1.476	1.430	1.305	1.598	1.851
Mn	0.000	0.000	0.000	0.000	0.019	0.000	0.000	0.000	0.014	0.008	0.000
Sum C (M1,M2,M3)	5	5	5	5	5	5	5	5	5	5	5
Mg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ni	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe2+	0.023	0.012	0.084	0.035	0.000	0.012	0.017	0.054	0.000	0.000	0.020
Mn	0.035	0.044	0.038	0.049	0.032	0.023	0.024	0.023	0.019	0.024	0.047
Ca	1.874	1.881	1.823	1.814	1.927	1.924	1.912	1.897	1 960	1.949	1.804
Na	0.067	0.063	0.055	0.102	0.040	0.041	0.047	0.025	0.022	0.027	0.128
Sum B (M4)	2	2	2	2	2	2	2	2	2	2	2
Na	0.322	0.261	0.039	0.251	0.031	0.140	0.227	0.013	0.051	0.161	0.355
K	0.144	0.128	0.007	0.222	0.018	0.129	0.213	0.008	0.006	0.031	0.201
Sum A	0.466	0.389	0.046	0.473	0.049	0.269	0.440	0.021	0.058	0.192	0.556
F	0.050	0.059	0.036	0.032	0.062	0.192	0.000	0.029	0.036	0.019	0.147
Cl	0.002	0.014	0.001	0.023	0.001	0.004	0.011	0.002	0.001	0.004	0.019
OH	1.948	1.926	1.963	1.945	1.936	1.804	1.989	1.968	1.963	1.977	1.834
Sum OH	2	2	2	2	2	2	2	2	2	2	2

Table 5: Amphibole analyses, Entwine Intrusion – cont'd.

Sample	99DS28	99DS40	99DS42b	99DS43	99DS43	99DS49d	99DS49e	99DS49e	99DS50f	99DS50b	99DS47
No. Anays	3	4	4	3 hb	2 actin	1	1 amph	3 amph	3 amph	2 amph	av of 4
Rock	14a	14b	14a	14a	14a	14a	14a	14a	14a	14a	14c
Area	Entwine	N. Entwine	N. Entwine	N. Entwine	N. Entwine	ER1 51.3m	ER1 61.0m	ER1 61.0m	ER10 34.2m	ER10 24.0m	N. Entwine
Easting	522261	528046	524859	522389	522389	525250	525250	525250	524950	524950	523400
Northing	5443167	5445553	5444767	5446702	5446702	5450400	5450400	5450400	5450600	5450600	5448200
Sum_cat	15.466	15.389	15.046	15.473	15.049	15.269	15.440	15.021	15.058	15.192	15.556
Fe2O3 calc	1.856	2.209	1.103	2.595	0.869	2.075	2.723	0.370	1.360	1.941	2.110
FeO calc	13.120	13.188	10.503	14.904	12.658	11.038	12.071	12.335	10.888	13.049	14.949
H2O calc	1.966	1.954	2.053	1.942	2.002	1.851	2.015	2.049	2.052	2.022	1.836
Total	99.229	99.540	99.445	99.526	99.492	99.320	99.742	99.628	99.932	99.624	99.685
Fe^{3+}/Fe^{tot}	0.113	0.131	0.086	0.135	0.058	0.145	0.169	0.026	0.101	0.118	0.113
$Fe^{tot}/(Fe^{tot}+Mg)$	0.393	0.398	0.282	0.479	0.336	0.341	0.405	0.317	0.299	0.393	0.459
These are Fe ratios calculated by the 13eCNK method to be used to determine suitability for hb barometry (Anderson and Smith)											
Fe^{3+}13eCNK	0.413	0.440	0.545	0.586	0.208	0.352	0.447	0.313	0.213	0.297	0.475
Fe^{3+}eCNK	1.415	1.427	0.819	1.563	1.416	1.218	1.344	1.202	1.237	1.512	1.623
Fe^{3+}/Fe^{tot}	0.226	0.236	0.399	0.273	0.128	0.224	0.250	0.207	0.147	0.164	0.227
$Fe^{tot}/(Fe^{tot}+Mg)$	0.391	0.395	0.279	0.475	0.335	0.339	0.402	0.315	0.298	0.392	0.456
Pressure and Temperature parameters											
P (kb) alT (Schmidt(1992)	**3.2**	**2.5**		**5.1**		**2.9**	**5.7**			**2.4**	**4.2**
TA (Holland and Blundy, 1994)	**744**	**716**	**550**	**757**	**532**	**682**	**740**	**438**	**536**	**626**	**703**
P (kb) Anderson and Smith (1995) using TA Holland and Blundy (1994)	**unsuitable**	**unsuitable**	**unsuitable**	**3.8**	**unsuitable**	**unsuitable**	**4.7**	**unsuitable**	**unsuitable**	**unsuitable**	**3.9**
unsuitable indicates that the amphibole fails the tests of Anderson and Smith (1995); analysis must have $Fe^{3+}/(Fe^{3+}+Fe^{2+})>.2$ and $.4<Fe^{tot}/(Fe^{tot}+Mg)<.65$											
Mineral Name	Magnesio-hornblende	Magnesio-hornblende	actinolite	Magnesio-hornblende	actinolite	Magnesio-hornblende	Magnesio-hornblende	actinolite	actinolite	Magnesio-hornblende	edenite

Table 6: Ilmenite and Magnetite analyses, Entwine Intrusion

Sample	99DS42b-33-ilm	99DS49c	99DS49f	99DS50d	99DS50i	99DS42b	99DS49f	99DS50d	99DS50i
Mineral	1 il	2 il	2 il	2 il	4 il	2 mag	3 mag	3 mag	2 mag
Rock	14a	14a	10d	14a	14a	14a	10b	14a	14a
Area	N. Entwine	ER1 42.9m	ER1 77.0m	ER10 26.5m	ER10 42.4m	N. Entwine	ER1 77.0m	ER10 26.5m	ER10 42.4m
Easting	524859	525250	525250	524950	524950	524859	525250	524950	524950
Northing	5444767	5450400	5450400	5450600	5450600	5444767	5450400	5450600	5450600
SiO2	0.02	0.01	0.01	0.01	0.01	0.03	0.01	0.02	0.04
TiO2	49.73	49.68	50.95	50.61	50.58	0.06	0.03	0.08	0.10
Nb2O5	0.01	0.05	0.01	0.04	0.03	0.00	0.00	0.00	0.00
Al2O3	0.02	0.02	0.00	0.02	0.04	0.09	0.02	0.32	0.23
Cr2O3	0.03	0.03	0.06	0.03	0.03	0.19	0.57	0.24	0.26
V2O5	0.18	0.15	0.09	0.16	0.22	0.88	0.55	0.76	0.74
MgO	0.05	0.04	0.03	0.05	0.05	0.03	0.03	0.04	0.05
MnO	2.19	2.74	3.02	1.45	2.05	0.02	0.01	0.02	0.04
FeO*	47.02	46.54	45.46	46.82	46.24	91.13	91.92	91.57	91.29
NiO	0.00	0.04	0.03	0.03	0.00	0.05	0.06	0.09	0.09
ZnO	0.00	0.07	0.01	0.03	0.02	0.03	0.00	0.03	0.03
Total	99.25	99.37	99.66	99.26	99.28	92.50	93.21	93.16	92.86
Fe2O3	4.78	5.00	2.92	2.89	2.84	65.59	66.79	66.04	65.88
FeO	42.71	42.04	42.84	44.21	43.68	32.11	31.82	32.14	32.01
Total	99.72	99.87	99.96	99.55	99.57	99.07	99.90	99.78	99.47
Cation Proportions O=3 for ilmenite, O=4 for magnetite									
Si	0.001	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.002
Ti	0.949	0.947	0.969	0.967	0.966	0.002	0.001	0.002	0.003
Nb	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000
Al	0.001	0.001	0.000	0.001	0.001	0.004	0.001	0.014	0.011
Cr	0.001	0.001	0.001	0.001	0.001	0.006	0.017	0.007	0.008
V	0.003	0.003	0.001	0.003	0.004	0.023	0.014	0.019	0.019
Mg	0.002	0.001	0.001	0.002	0.002	0.002	0.001	0.002	0.003
Mn	0.047	0.059	0.065	0.031	0.044	0.001	0.000	0.001	0.001
Fe+3	0.091	0.095	0.056	0.055	0.054	1.917	1.937	1.914	1.916
Fe+2	0.906	0.891	0.906	0.939	0.927	1.043	1.026	1.035	1.035
Ni	0.000	0.001	0.001	0.001	0.000	0.002	0.002	0.003	0.003
Zn	0.000	0.001	0.000	0.001	0.000	0.001	0.000	0.001	0.001
SUM	2	2	2	2	2	3	3	3	3
ilmenite	95.01	94.77	96.92	96.94	96.95				
geikelite	0.21	0.15	0.10	0.21	0.21				
hematite	4.79	5.08	2.97	2.85	2.84				
TOTAL	100.00	100.00	100.00	100.00	100.00				

Table 7: Analyses of Chlorite, Entwine Intrusion

Sample	99DS46	99DS49c	99DS49c2	99DS49e	99DS50b	99DS50f
No ansys	3 chl	1 chl	1 chl	3 chl	3 chl	4 chl
Rock	14a	14a	14a	14a	14a	14a
Area	N. Entwine	ER1 42.9m	ER1 42.9m	ER1 61.0m	ER10 24.0m	ER10 34.2m
Easting	525600	525250	525250	525250	524950	524950
Northing	5450350	5450400	5450400	5450400	5450600	5450600
SiO2	24.55	25.91	30.84	27.31	27.36	28.14
TiO2	0.01	0.00	0.04	0.02	0.45	0.76
Al2O3	21.81	19.31	14.64	17.45	17.08	17.04
Cr2O3	0.01	0.00	0.04	0.01	0.03	0.03
MgO	5.53	11.86	15.28	8.13	10.03	10.16
CaO	0.42	0.07	1.27	0.07	0.12	0.23
MnO	0.20	0.21	0.21	0.22	0.17	0.14
FeO	36.20	29.59	25.38	35.82	34.07	32.28
Na2O	0.11	0.03	0.07	0.03	0.03	0.02
K2O	0.07	0.01	0.03	0.07	0.22	1.11
F	0.04	0.00	0.06	0.04	0.03	0.03
Cl	0.02	0.00	0.01	0.03	0.01	0.01
Total	88.98	87.00	87.88	89.20	89.60	89.95
H2O calc	10.85	11.02	11.39	10.93	11.08	11.19
O=F+Cl	0.02	0.00	0.03	0.03	0.01	0.02
Total	99.81	98.02	99.24	100.11	100.67	101.12
Cations on the basis of 36 (O,OH,F,Cl) with OH+F+Cl=16; all Fe as FeO						
Si	5.413	5.638	6.478	5.977	5.914	6.024
AlIV	2.587	2.362	1.522	2.023	2.086	1.976
Sum_T	8	8	8	8	8	8
AlVI	3.077	2.586	2.099	2.475	2.262	2.319
Ti	0.002	0	0.006	0.003	0.073	0.122
Fe2	6.674	5.385	4.458	6.557	6.158	5.778
Cr	0.002	0	0.007	0.002	0.005	0.004
Mn	0.038	0.039	0.037	0.041	0.031	0.026
Mg	1.819	3.847	4.785	2.652	3.233	3.243
Ca	0.099	0.016	0.286	0.015	0.027	0.053
Na	0.048	0.013	0.029	0.013	0.013	0.007
K	0.02	0.003	0.008	0.019	0.062	0.302
Cations	19.779	19.889	19.715	19.777	19.864	19.854
CF	0.06	0	0.08	0.061	0.042	0.047
CCl	0.016	0	0.007	0.022	0.004	0.011
OH	15.962	16	15.957	15.958	15.977	15.971
O	36	36	36	36	36	36
Fe/(Fe+Mg)	0.79	0.58	0.48	0.71	0.66	0.64
Mg/(Mg+Fe)	0.21	0.42	0.52	0.29	0.34	0.36
Name	Ripidolite	Brunsvigite	Diabantite	Brunsvigite	Brunsvigite	Brunsvigite

Table 8: Analyses of Epidote Group Minerals, Entwine Intrusion.

Sample	99DS42b	99DS42b	99DS49c	99DS49d	99DS49e	99DS46	99DS49e	99DS50b	99DS50f
Mineral	1 zo	1 ep	1 ep	1 zo	1 ep	1 ep	3 ep	3 ep	3 ep
Rock	14a	14a	14a	14a	14a	14a	14a	14a	14a
Area	N. Entwine	N. Entwine	ER1 42.9m	ER1 51.3m	ER1 61.0m	N. Entwine	ER1 61.0m	ER10 24.0m	ER10 34.2m
Easting	524859	524859	525250	525250	525250	525600	525250	524950	524950
Northing	5444767	5444767	5450400	5450400	5450400	5450350	5450400	5450600	5450600
SiO2	38.21	37.30	37.89	38.12	36.88	37.60	37.46	37.71	37.63
TiO2	0.02	0.00	0.02	0.05	0.02	0.02	0.06	0.04	0.03
Al2O3	28.66	24.10	24.81	29.44	24.38	22.70	22.36	23.99	23.70
Cr2O3	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01
Fe2O3	6.12	12.06	11.08	5.37	11.63	14.01	14.39	12.07	12.48
MgO	0.09	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.00
CaO	24.19	23.90	23.64	23.65	24.04	22.43	22.54	22.98	22.97
MnO	0.04	0.03	0.01	0.01	0.02	0.03	0.05	0.11	0.16
Na2O	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.02	0.00
K2O	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01
H2O calc	1.92	1.88	1.89	1.92	1.87	1.86	1.86	1.87	1.87
Total	99.26	99.29	99.35	98.56	98.84	98.66	98.72	98.84	98.86
Cations on the basis of 13 (O,OH) with OH=1									
Si	2.983	2.979	3.006	2.982	2.959	3.027	3.021	3.016	3.014
AlIV	0.017	0.021	0	0.018	0.041	0	0	0	0
Sum_T	3	3	3.006	3	3	3.027	3.021	3.016	3.014
AlVI	2.618	2.246	2.318	2.694	2.263	2.152	2.124	2.259	2.235
Ti	0.001	0	0.001	0.003	0.001	0.001	0.004	0.002	0.002
Cr	0.001	0	0	0	0	0	0	0.002	0.001
Fe3	0.359	0.724	0.661	0.316	0.701	0.848	0.872	0.726	0.751
Mg	0.01	0.002	0	0	0	0	0	0.001	0
Mn	0.003	0.002	0.001	0.001	0.001	0.002	0.003	0.007	0.011
Na	0	0	0.002	0	0	0	0	0.002	0
Ca	2.023	2.045	2.01	1.982	2.066	1.935	1.948	1.969	1.971
K	0	0	0	0	0	0.001	0	0.001	0.001
Sum_cats	8.015	8.019	7.999	7.996	8.032	7.966	7.972	7.985	7.986

Table 9: Chalcopyrite analyses, Entwine Intrusion

Sample	99DS42b	99DS49c	99DS49f	99DS50b	99DS50d
Mineral	1 Ccp	2 Ccp	1 Ccp	4 Ccp	3 Ccp
Rock	14a	14a	10b	14a	14a
Area	N. Entwine	ER1 42.9m	ER1 77.0m	ER10 24.0m	ER10 26.5m
Easting	524859	525250	525250	524950	524950
Northing	5444767	5450400	5450400	5450600	5450600
Element wt%					
S	35.46	35.23	34.77	34.73	35.02
Fe	30.48	30.48	30.47	30.46	30.20
Ni	0.35	0.00	0.01	0.05	0.00
Co	0.00	0.00	0.00	0.00	0.00
Cu	34.22	34.61	34.77	34.13	34.31
Zn	0.01	0.01	0.00	0.00	0.06
Se	0.01	0.00	0.01	0.00	0.01
Te	0.00	0.00	0.00	0.01	0.00
Total	100.54	100.34	100.03	99.39	99.61
Cation proportions					
S	2.014	2.008	1.992	2.000	2.010
Fe	0.994	0.997	1.002	1.007	0.995
Ni	0.011	0.000	0.000	0.001	0.000
Co	0.000	0.000	0.000	0.000	0.000
Cu	0.981	0.995	1.005	0.992	0.993
Zn	0.000	0.000	0.000	0.000	0.002
Se	0.000	0.000	0.000	0.000	0.000
Te	0.000	0.000	0.000	0.000	0.000
Total	4	4	4	4	4

Table 10: Pyrite analyses, Entwine Intrusion

Sample	99DS42b	99DS42b	99DS49c	99DS49f	99DS49f	99DS50B	99DS50B	99DS50d
Mineral	1py	1py	1py	1py	1py	1py	1py	1py
Rock	14a	14a	14a	10b	10b	14a	14a	14a
Area	N. Entwine	N. Entwine	ER1 42.9m	ER1 77.0m	ER1 77.0m	ER10 24.0m	ER10 24.0m	ER10 26.5m
Easting	524859	524859	525250	525250	525250	524950	524950	524950
Northing	5444767	5444767	5450400	5450400	5450400	5450600	5450600	5450600
Element Weight %								
S	52.80	53.03	53.81	53.43	53.12	53.11	53.48	53.12
Fe	45.61	43.89	46.79	45.93	44.66	45.65	46.72	45.89
As	0.02	0.03	0.00	0.03	0.04	0.03	0.00	0.00
Ni	0.04	0.01	0.01	0.04	1.65	0.02	0.05	0.03
Co	0.87	2.53	0.01	0.27	0.39	0.82	0.00	0.10
Ag	0.00	0.00	0.00	0.01	0.02	0.01	0.01	0.00
Total	99.33	99.50	100.63	99.70	99.88	99.64	100.27	99.13
Cation proportions								
S	1.993	1.998	2.001	2.004	1.995	1.997	1.997	2.004
Fe	0.988	0.949	0.999	0.989	0.963	0.985	1.002	0.994
As	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
Ni	0.001	0.000	0.000	0.001	0.034	0.000	0.001	0.001
Co	0.018	0.052	0.000	0.005	0.008	0.017	0.000	0.002
Ag	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	3	3	3	3	3	3	3	3

Table 11: Analyses of pyrrhotite and pentlandite, Entwine Intrusion

Sample	99DS42b	99DS50d	99DS50d	99DS50d	99DS50d
Mineral	1 pyrrhotite	1 pyrrhotite	1 pyrrhotite	1 pentlandite	1 pentlandite
Rock	14a	14a	14a	14a	14a
Area	N. Entwine	ER10 26.5m	ER10 26.5m	ER10 26.5m	ER10 26.5m
Easting	524859	524950	524950	524950	524950
Northing	5444767	5450600	5450600	5450600	5450600
Element wt%					
S	39.04	39.72	39.45	33.57	32.87
Fe	58.91	58.99	58.96	27.84	27.67
Ni	0.83	0.78	0.80	34.79	35.00
Co	0.04	0.06	0.07	3.68	3.74
Ag	0.02	0.02	0.02	0.01	0.00
Total	98.85	99.59	99.30	99.89	99.28
Cation proportions					
S	1.065	1.073	1.069	0.952	0.940
Fe	0.922	0.915	0.918	0.453	0.454
Ni	0.012	0.012	0.012	0.539	0.547
Co	0.001	0.001	0.001	0.057	0.058
Ag	0.000	0.000	0.000	0.000	0.000
Total	2	2	2	2	2

Table 12: Analyses of millerite, Entwine Intrusion

Sample	99DS50B	99DS50B	99DS50B
Mineral	1 millerite	1 millerite	1 millerite
Rock	14a	14a	14a
Area	ER10 24.0m	ER10 24.0m	ER10 24.0m
Easting	524950	524950	524950
Northing	5450600	5450600	5450600
Element wt%			
Si	1.011	0.492	0.926
S	38.903	40.141	39.053
Fe	4.710	4.317	4.828
Ni	51.004	52.510	50.005
Co	0.291	0.296	0.301
Ag	0.010	0.010	0.000
Total	95.929	97.766	95.113
Cation proportions			
Si	0.033	0.016	0.030
S	1.099	1.115	1.110
Fe	0.076	0.069	0.079
Ni	0.787	0.796	0.776
Co	0.004	0.004	0.005
Ag	0.000	0.000	0.000
Total	2	2	2

Table 13: Analyses of electrum and PGE tellurides, Entwine Intrusion

Sample	99DS50d	99DS50F	99DS50f	99DS50f	99DS50b	99DS50b	99DS46	99DS46
Mineral	unknown	electrum	electrum	moncheite	moncheite	$(Pd,Bi)_2Te$?	merenskyite?	Pd(Te,Bi)?
Rock	14a	14a	14a	14a	14a	14a	14a	14a
Area	ER10 26.5m	ER10 34.2m	ER10 34.2m	ER10 34.2m	ER10 24.0m	ER10 24.0m	N. Entwine	N. Entwine
Easting	524950	524950	524950	524950	524950	524950	525600	525600
Northing	5450600	5450600	5450600	5450600	5450600	5450600	5450350	5450350
(element %)								
Si	1.74	nd	nd	nd	nd	nd	nd	nd
S	12.36	1.76	1.72	nd	nd	nd	nd	nd
Fe	nd	nd	nd	1.48	nd	0.96	1.16	1.78
Pt	nd	nd	nd	39.67	34.42	nd	nd	nd
Pd	nd	nd	nd	nd	2.81	38.65	23.77	35.94
Bi	28.64	nd	nd	9.98	15.43	28.1	41.27	37.23
Te	nd	nd	nd	47.77	44.03	32.12	33.97	24.31
Sb	nd	nd	nd	0.71	nd	1.06	1.43	1.7
Pb	43.9	nd	nd	nd	nd	0.71	nd	nd
Au	nd	67.22	66.81	1.3	nd	nd	nd	nd
Ag	4.46	30.26	30.5	nd	nd	nd	nd	nd
Total	91.1	99.24	99.03	100.91	96.69	101.6	101.6	100.96
Atomic Proportions								
Si	0.222	-	-	-	-	-	-	-
S	1.381	0.081	0.079	-	-	-	-	-
Fe	-	-	-	0.120	-	0.022	0.087	0.042
Pt	-	-	-	0.918	0.851	-	-	-
Pd	-	-	-	-	0.127	0.466	0.931	0.449
Bi	0.491	-	-	0.216	0.356	0.173	0.823	0.237
Te	-	-	-	1.690	1.665	0.323	1.110	0.253
Sb	-	-	-	0.026	-	0.011	0.049	0.019
Pb	0.759	-	-	-	-	0.004	-	-
Au	-	0.504	0.502	0.030	-	-	-	-
Ag	0.148	0.415	0.419	-	-	-	-	-
No. cations	3	1	1	3	3	1	3	1

Table 14: Temperature and Pressure determinations, Entwine Stock

Sample	Thermometer/Barometer	T°C	P (kbar)
99DS46	2 pyroxene thermometer (Berman 1991)	940	10 (assumed)
99DS49e	2 pyroxene thermometer (Berman 1991)	850	10 (assumed)
99DS46	SCAn barometer (McCarthy and Patino Douce 1998)	900 (assumed)	4.9
99DS49c	SCAn barometer (McCarthy and Patino Douce 1998)	900 (assumed)	9.9
99DS49d	SCAn barometer (McCarthy and Patino Douce 1998)	900 (assumed)	5.4
99DS49e	SCAn barometer (McCarthy and Patino Douce 1998)	900 (assumed)	10.2
99DS43	Holland and Blundy (1994), Anderson and Smith (1995)	757	3.8
99DS47	Holland and Blundy (1994), Anderson and Smith (1995)	703	3.9
99DS102	Holland and Blundy (1994), Anderson and Smith (1995)	687	3
99DS117	Holland and Blundy (1994), Anderson and Smith (1995)	691	4.1

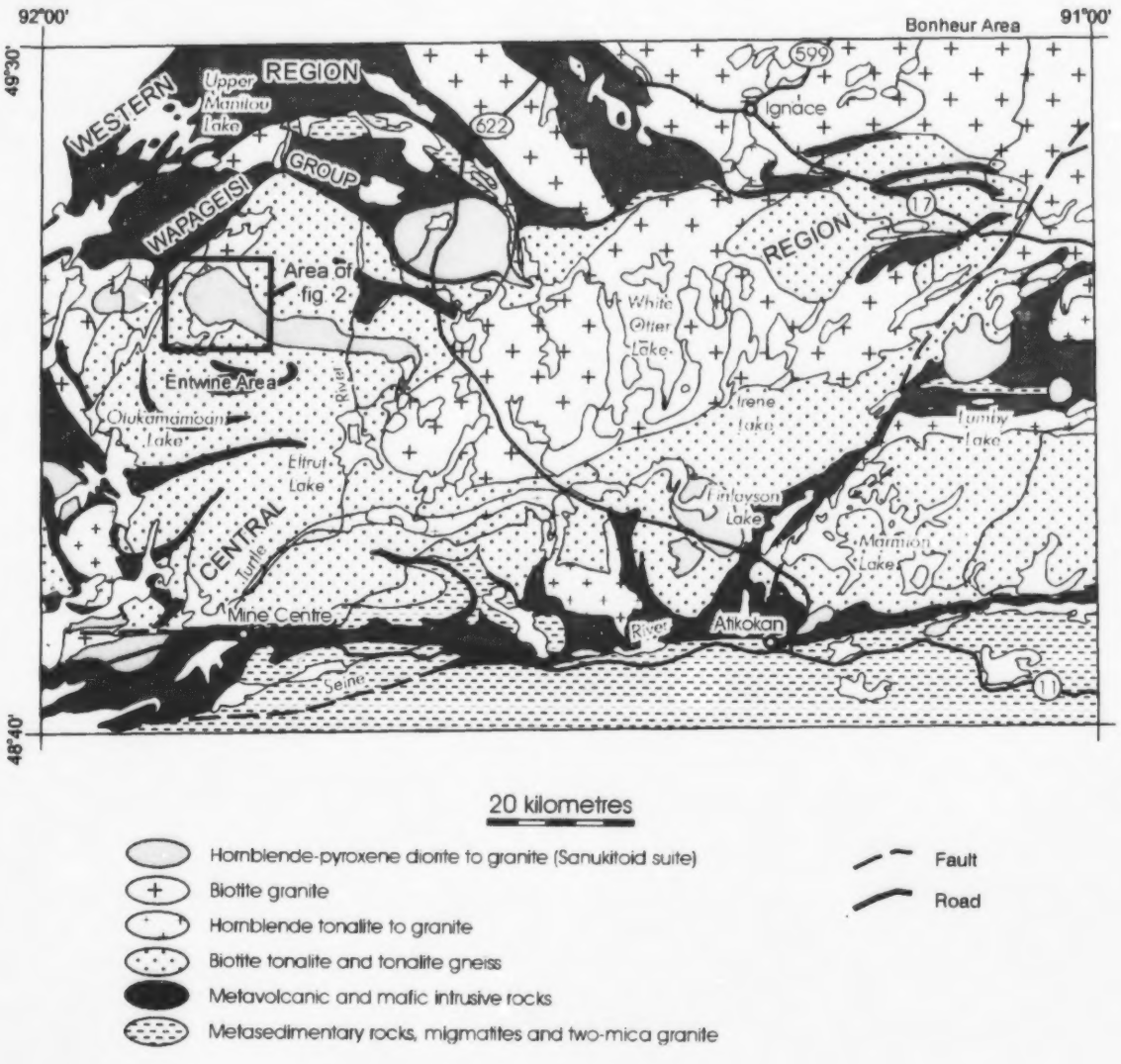

Figure 1: Geology of the south-central Wabigoon Subprovince. The Entwine Lake area is outlined.

Figure 2: Geology of the western Entwine stock.

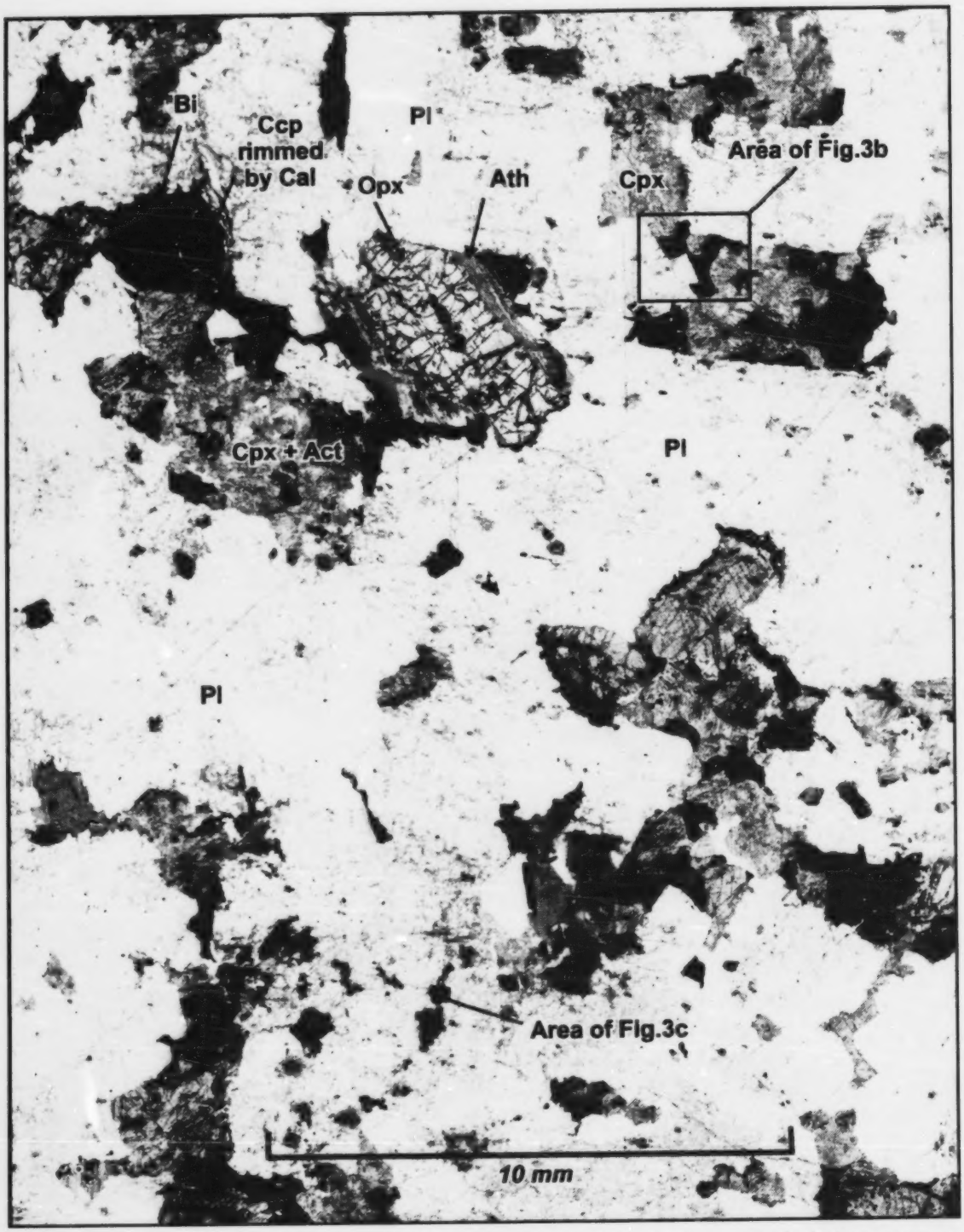

Figure 3a: A thin section of sample 99DS46 representative of fresh diorite is composed of clinopyroxene + orthopyroxene + biotite + plagioclase and secondary amphibole + chlorite + calcite + quartz + zoesite + sericite. Opaque minerals are magnetite, ilmenite, chalcopyrite, pyrite and pyrrhotite. The sample assayed 130 ppb Au, 169 ppb Pt and 285 ppb Pd.

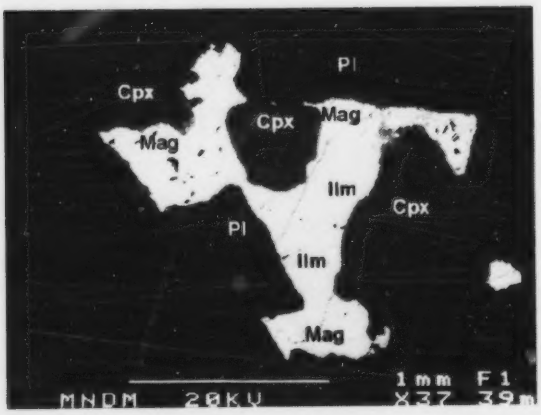

Figure 3b: Sample 99DS46. An irregular composite grain of magnetite and ilmenite in contact with clinopyroxene and plagioclase.

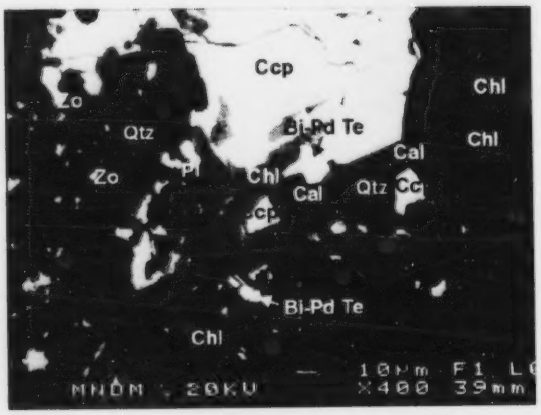

Figure 3c: Sample 99DS46. Bright grains of Bi-Pd telluride occur with chalcopyrite, chlorite, quartz, zoesite, calcite, and plagioclase.

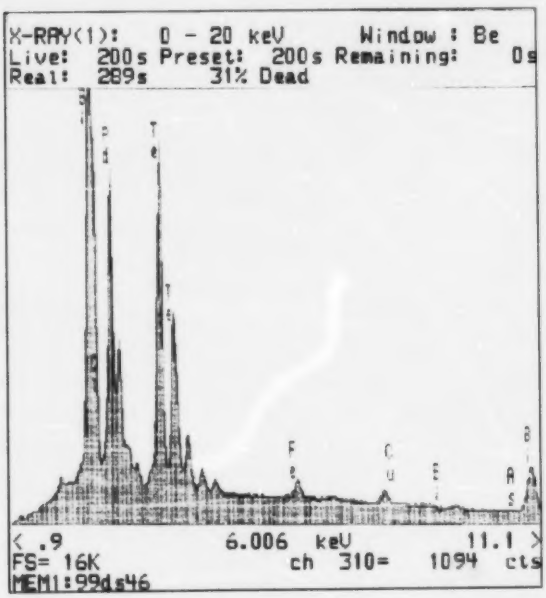

Figure 3d: Energy spectrum of the large Bi-Pd telluride grain in Figure 3c.

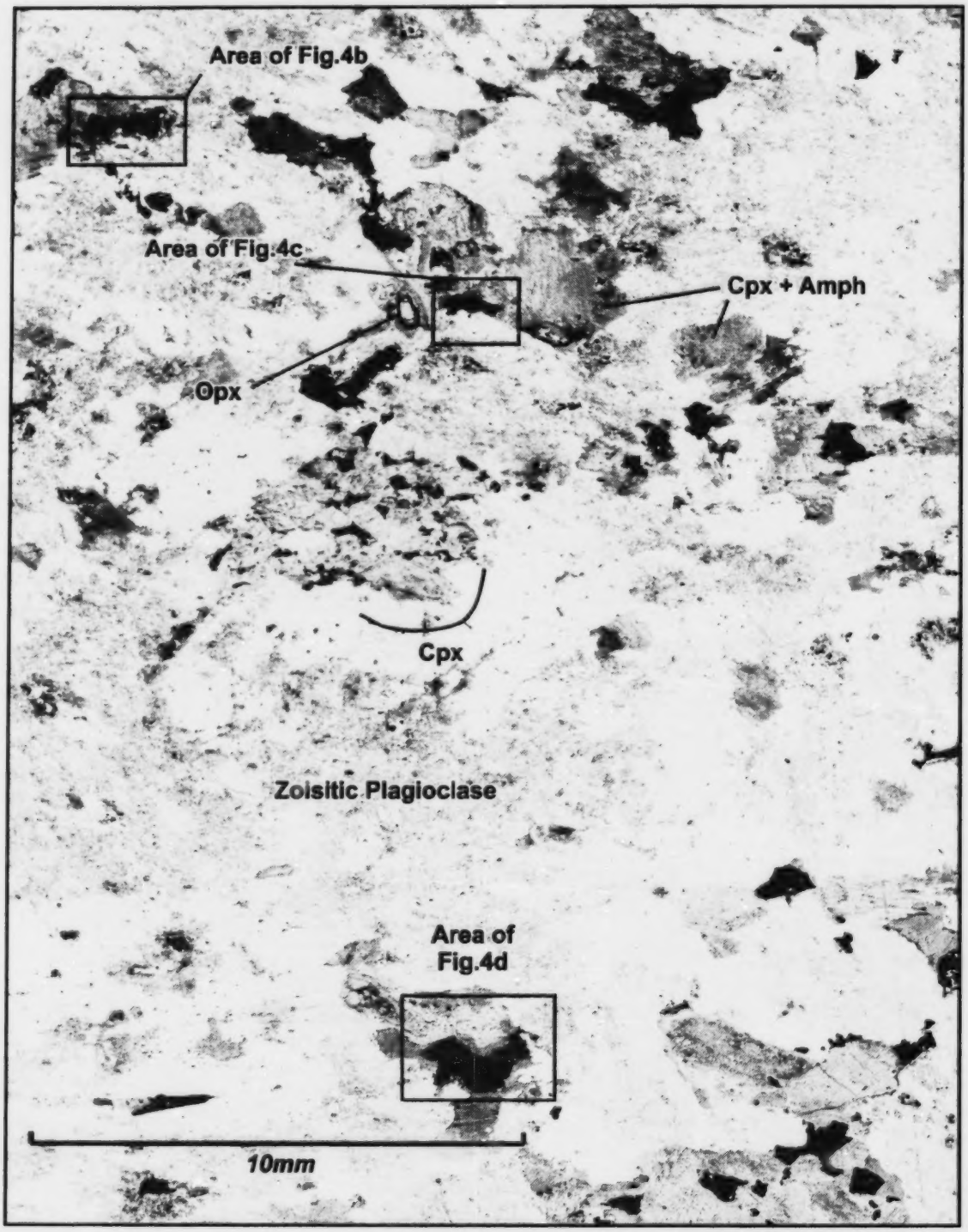

Figure 4a: Thin section of sample 99DS49E from 61. m depth in borehole ER1 represents low to moderately altered diorite. The rock is composed of clinopyroxene +orthopyroxene + amphibole + biotite + plagioclase with secondary epidote + zoisite + chlorite + quartz + albite + sericite. Opaque minerals include magnetite, ilmenite, chalcopyrite, pyrite, pyrrhotite and pentlandite with rare galena and palladium-bismuthide. The sample assayed 175 ppb Au, 201 ppb Pt and 349 ppb Pd.

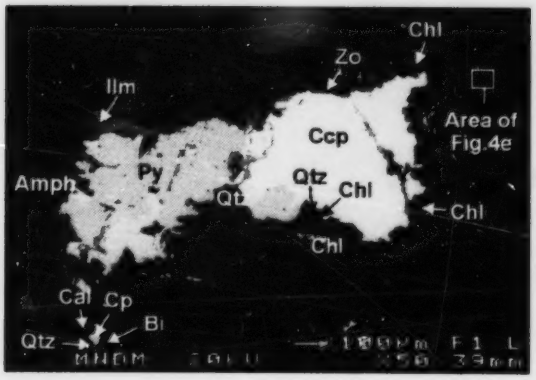

Figure 4b: A composite grain of pyrite + chalcopyrite + minor ilmenite in an assemblage of amphibole + biotite + plagioclase + chlorite - epidote + zoesite.

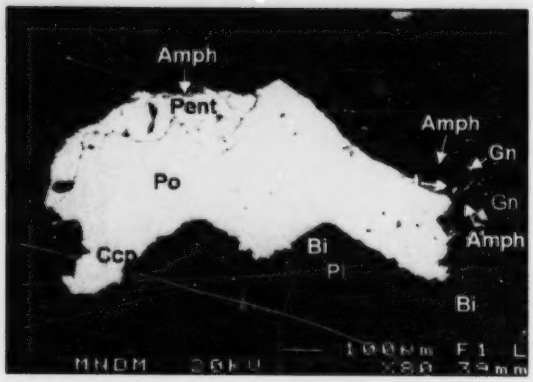

Figure 4c: A composite grain of pyrrhotite + pentlandite + chalcopyrite is rimmed by biotite in an assemblage of biotite + 2 varieties of amphibole + plagioclase.

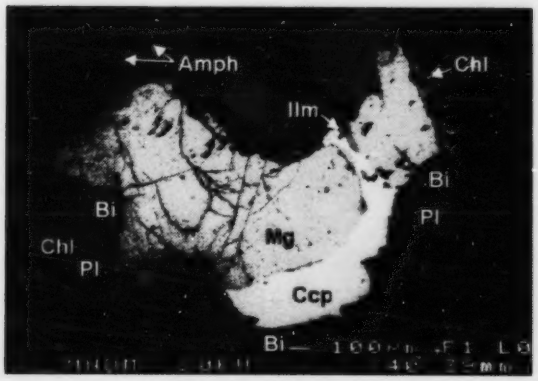

Figure 4d: A grain of magnetite with chalcopyrite and minor ilmenite is rimmed by biotite in an assemblage of biotite + plagioclase + amphibole.

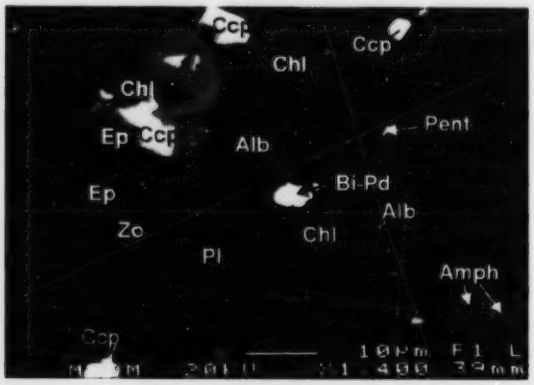

Figure 4e: Close-up of palladium-bismuthide grain in Figure 4b.

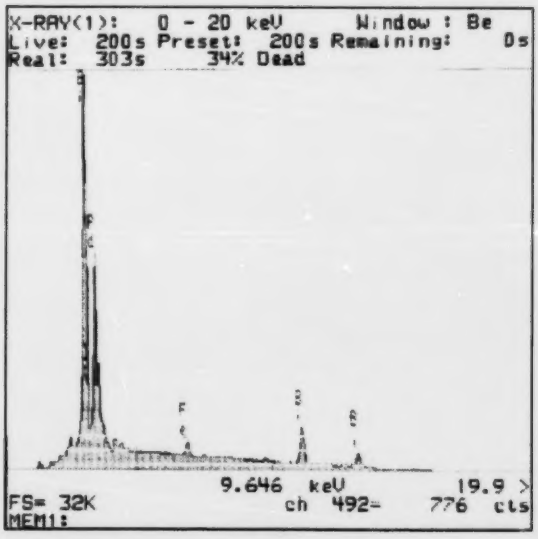

Figure 4f: Energy spectrum of palladium-bismuthide.

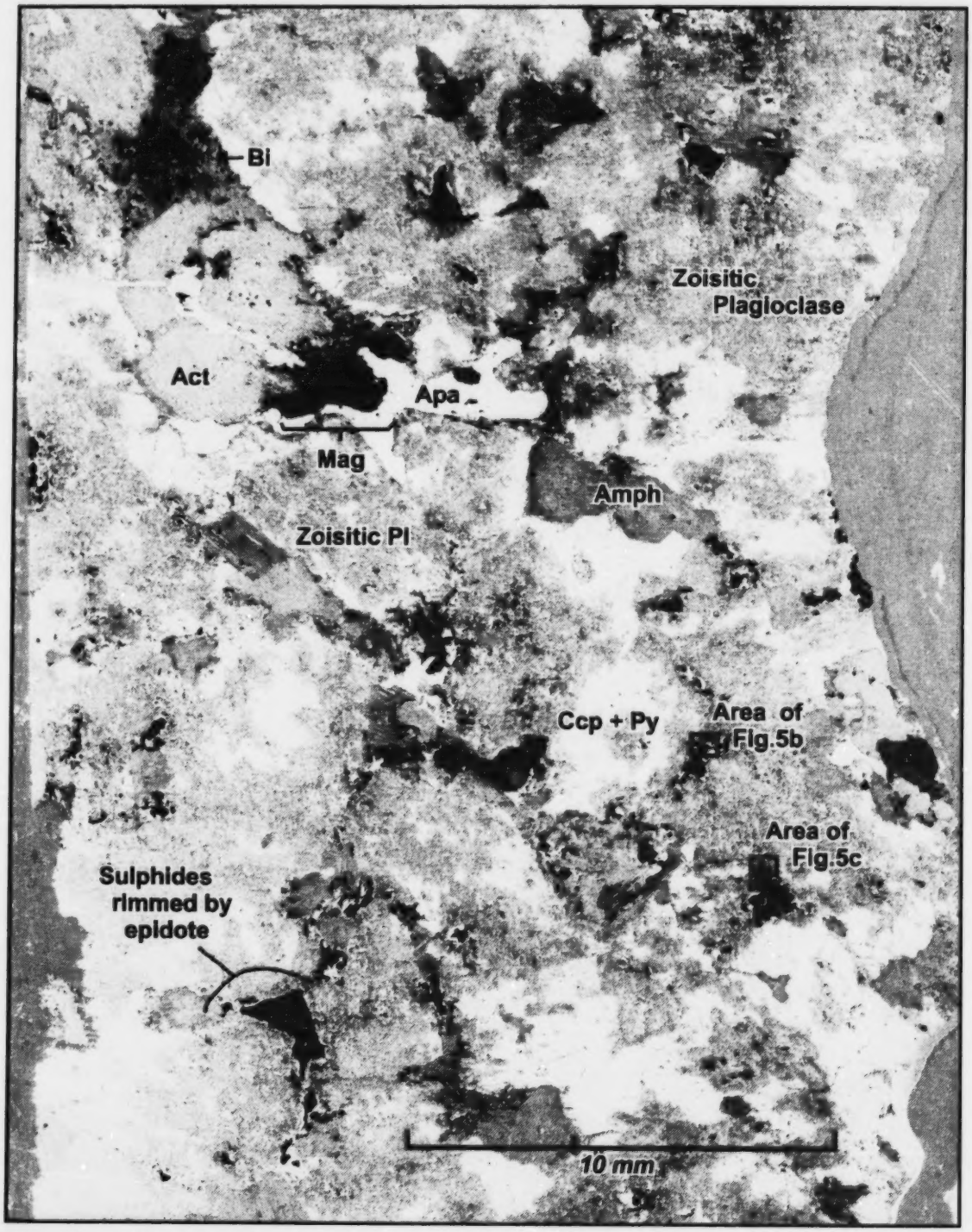

Figure 5a: Thin section of sample 99DS50F from 34.2m depth in borehole ER10 is representative of moderately altered diorite. The rock is composed of amphibole, biotite and zoisitic plagioclase as well as chlorite, epidote, apatite, quartz and calcite. Opaque minerals are magnetite, ilmenite, chalcopyrite, pyrite, pyrrhotite, pentlandite and rare galena, electrum and Pt-Bi telluride. The sample assayed 307 ppb Au, 349 ppb Pt and 593 ppb Pd.

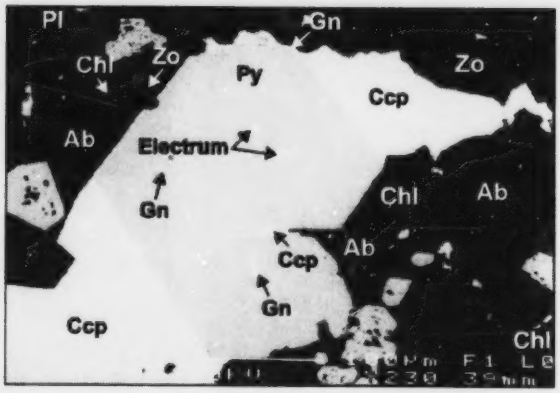

Figure 5b: Sample 99DS50F. Bright grains of electrum and galena occur in pyrite associated with chalcopyrite + chlorite + albite + zoesite.

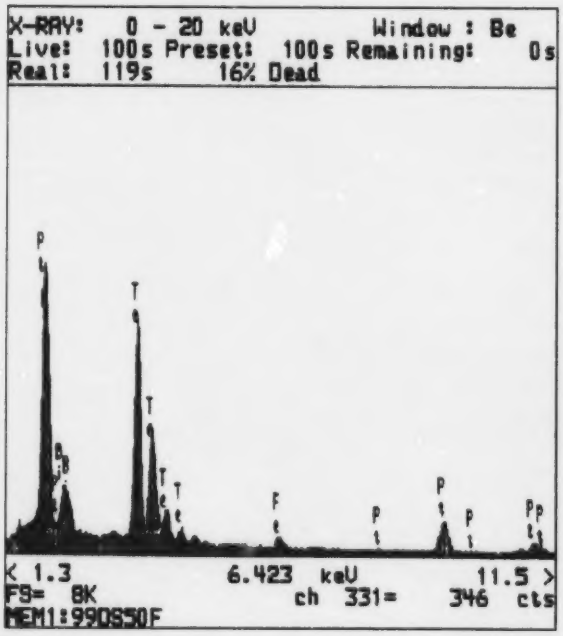

Figure 5e: Energy spectrum of the large Pt-Bi telluride grain in Figure 5c.

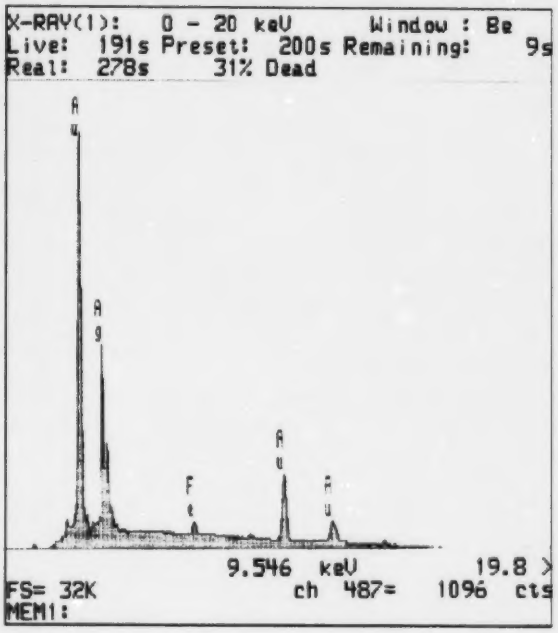

Figure 5d: Energy spectrum of electrum grain in Figure 5b.

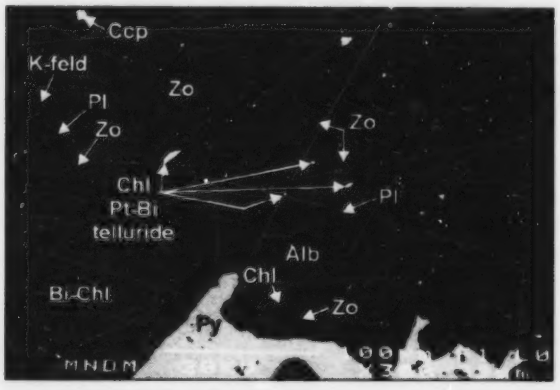

Figure 5c: Sample 99DS50F. Bright grains of platinum -bismuth telluride occur with biotite + zoesite + chlorite + albite + K-feldspar + pyrite + chalcopyrite.

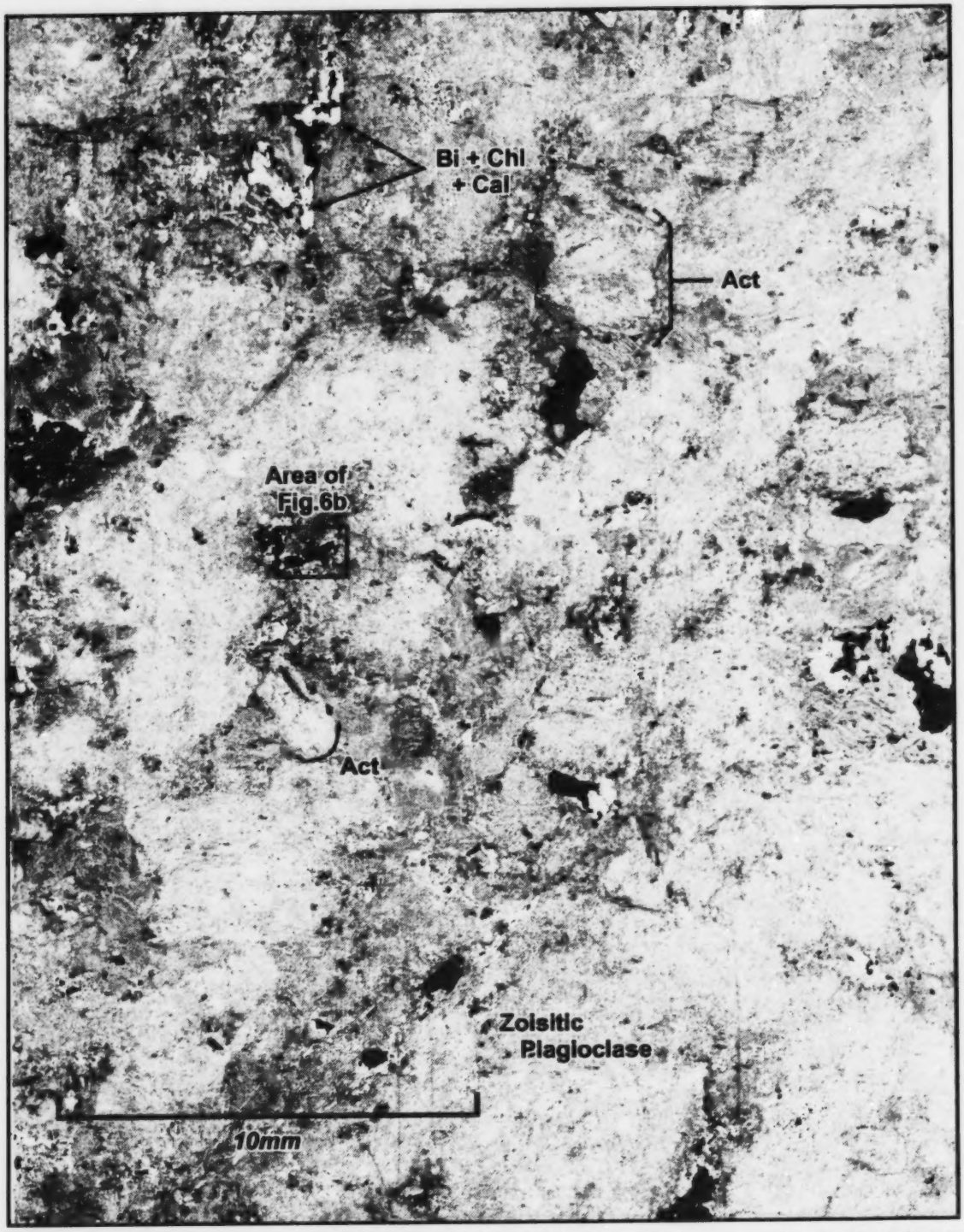

Figure 6a: A thin section of sample 99DS50B from 24m depth in borehole ER10 represents strongly altered diorite. The rock is composed of amphibole + biotite + zoisitic plagioclase + chlorite + epidote + titanite + sericite + quartz + calcite. Opaque minerals are chalcopyrite and pyrite with minor magnetite, ilmenite, pentlandite, and millerite and PGE tellurides. The sample assayed 231 ppb Au, 335 ppb Pt and 590 ppb Pd.

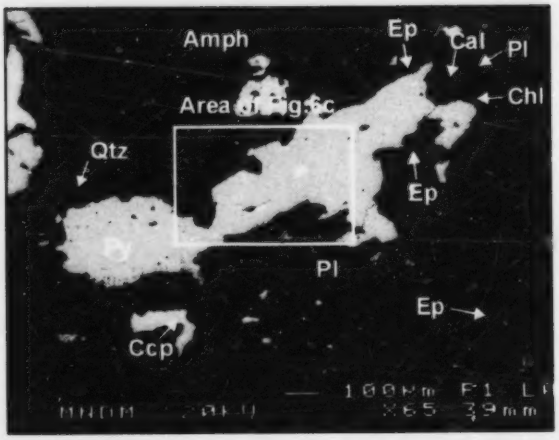

Figure 6b: A pyrite grain containing pentlandite and PGE telluride grains occurs with an assemblage of epidote + amphibole + plagioclase + chlorite + calcite + quartz and chalcopyrite.

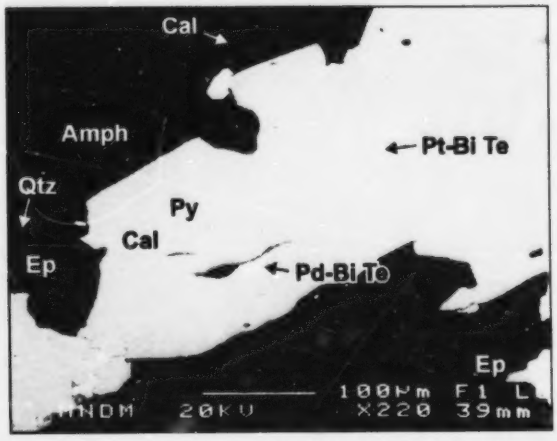

Figure 6c: Close-up of bright Pd-Bi telluride and Pt-Bi telluride grains in pyrite.

Table of compositions: PGE-telluride grains in Figure 6c.

Sample	99DS50b	99DS50b
Mineral	merenskyite	(Pd,Bi)$_2$Te?
Rock	14a	14a
Area	ER10 24.0m	ER10 24.0m
Easting	524950	524950
Northing	5450600	5450600
(element %)		
Si	nd	nd
S	nd	nd
Fe	nd	0.96
Pt	34.42	nd
Pd	2.81	38.65
Bi	15.43	28.1
Te	44.03	32.12
Sb	nd	1.06
Pb	nd	0.71
Au	nd	nd
Ag	nd	nd
Total	96.69	101.6
Atomic Proportions		
Si	-	-
S	-	-
Fe	-	0.022
Pt	0.851	-
Pd	0.127	0.466
Bi	0.356	0.173
Te	1.665	0.323
Sb	-	0.011
Pb	-	0.004
Au	-	-
Ag	-	-
No. cations	3	1

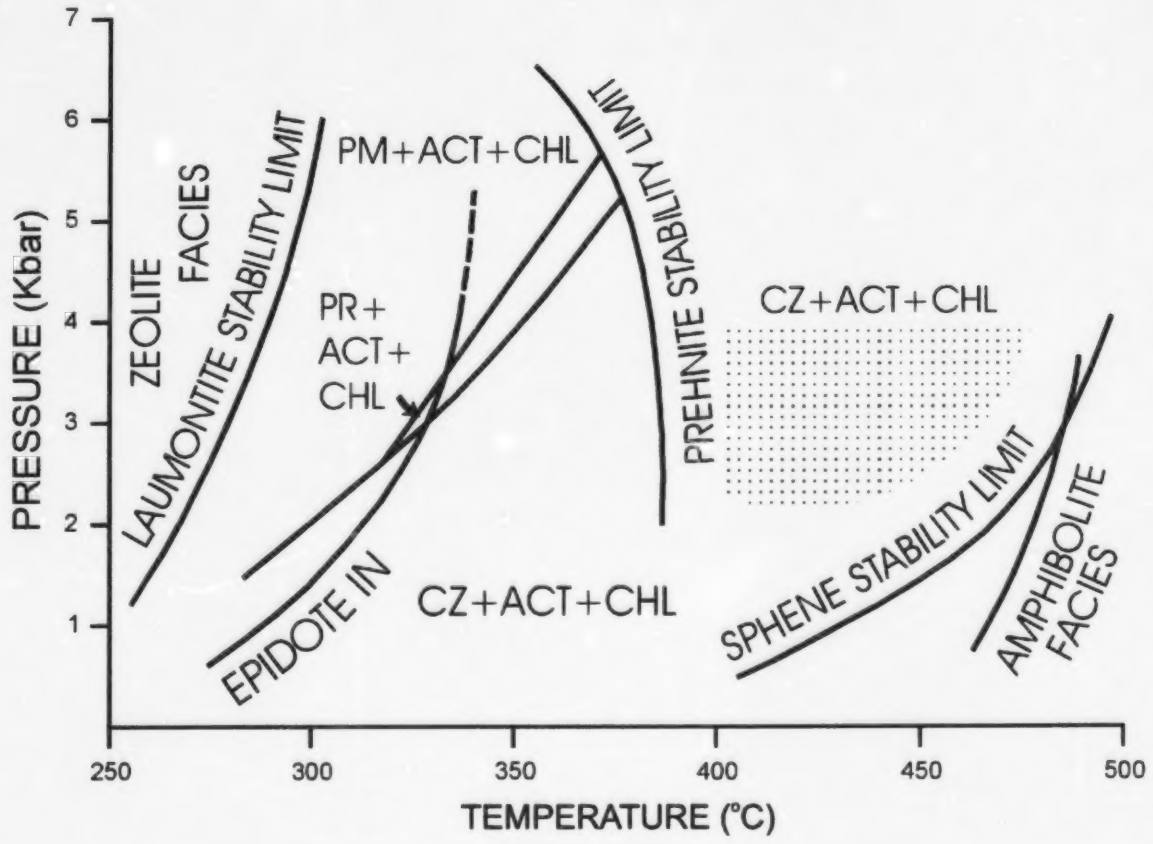

Figure 7: Pressure-temperature plot showing stability fields of index minerals and assemblages, and the estimated P-T field (stippled), in which PGE minerals were mobilized. Prehnite and laumontite stability limits are from Liou (1971a,b); epidote and sphene stability limits are from Moody, Meyer and Jenkins (1983); greenschist-amphibolite facies boundary is from Liou, Kunoyoshi and Ito (1974). Phase relations among ACT (actinolite), CHL (chlorite), CZ (clinozoisite), PM (pumpellyite) are from Schiffman and Liou (1980).

Metric Conversion Table

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
		LENGTH			
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
		AREA			
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
		VOLUME			
1 cm^3	0.061 023	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.307 951	cubic yards	1 cubic yard	0.764 554 86	m^3
		CAPACITY			
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
		MASS			
1 g	0.035 273 962	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 747	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 622 6	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311 3	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 90**	t
		CONCENTRATION			
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	31.103 477	grams per ton (short)
1 gram per ton (short)	0.032 151	ounces (troy) per ton (short)
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.